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ABSTRACT

This document contains the text of 71 papers presented at a national conference dealing with the relationships among science, technology and society (STS) with particular emphasis on technological literacy. Topics include: (1) emerging ideas and challenges; (2) STS in developing countries; (3) STS and government; (4) frameworks and concepts in STS education; (5) programs and courses for K-12, college/university, teacher training, continuing education, and research settings; (6) STS and women; (7) STS and values education; and (8) educational technology. Introductory remarks by Rustum Roy and an afterward by Leonard J. Waks are included. (CW)

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Volume 7, Numbers 5 and 6 1987

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EDITORIAL

TECHNOLOGICAL LITERACY - PHASE II BEGINS

Rustum Roy

Thomas Jefferson wrote that it was society's duty -- when confronted by citizens unable to understand an issue -- "to inform their discretion by education." Little did he imagine that within a scarce 200 years, the vast majority of citizens and their representatives of his, then, new republic, would not have the knowledge and understanding to vote intelligently on perhaps a majority of the issues, confronting the country. That is the reality. And our initial response must be to exert every conceivable efffort to inform the voters' "discretion by education." The entire STS effort is devoted -- in part -- to precisely such education for contemporary citizenship.

This volume contains the written record of the third in a series of conferences built around the theme - last year I referred to it as also being a slogan - of Technological Literacy. Yet our very success in gathering a thousand persons to attend such a conference is a sign that we may now be past the first phase - getting attention paid to a new need in the education of citizens. It is clear that the community is now ready to move to Phase II in this enterprise.

In parallel with the effort to introduce the teaching of STS, it behooves us to ask the question whether, given the realities of the rate of change or improvement in our educational systems and the rate of change of technology and science, and in what sense this race can ever be won. Responding to this question instantly makes it clear that technological literacy cannot mean even the most meagre knowledge on the part of the public, about the ever expanding circumference of the S/T universe. What then can we realistically expect from the myriad efforts -- many described in this volume -- in the STS approach to this problem?

What can we change if not just the content of the courses? My own reflection on this topic goes back to Norman Cousins, founder and Editor, for a generation, of the Saturday Review of Literature with whom I had the good fortune to work on some committees in the 1970's. Cousins, one of the great figures in the literary world, had moved into the field of medicine because of a personal experience in alternative routes to healing. In short order he was able to write and sound like someone trained in the field. I asked him why this was possible. His answer gave me the clue; he said: "I never thought there was anything basic there (in the medical world) which I could not understand. I was never afraid of trying to pick up the gist of the argument and to ask about everything I didn't understand." The key to technolgoical literacy may have little to do with content. The key lies instead with a change in attitude: From fear to familiarity. Like learning that St. Bernard's are just dogs. Not only must we eradicate science-phobia, we must instill a new sense of empowerment that essentially all citizens will feel that if, where, and when they wish they can learn enough about the technological issue to be a functioning citizen in our techno-democratic society.

I would hope that many of us concerned with the content of technological literacy, would realize that the change of psychological attitude to technology and science may be both the quickest and the most effective step in increasingly technological literacy.

In the volume which follows, we have collected many of the papers presented at the 3rd Annual TLC into eight sections. These sections move from the broadest challenges ahead, through the twin themes of the Conference "Technology and Development" and "Technology and Democracy," to the existential realities of STS education in concepts, programs and courses designed to address these themes. It is worth recording that in spite of the wide diversity of speakers who spoke on the issue of development, there was an extraordinary amount of agreement on the failure of the classical model for third world development. The issues of democracy in a technological society are less clearly drawn, and only now being opened up. One that is sure to surface soon, however, is the matter of the applicability of democratic procedures in selecting the goals for science and technology. There will be plenty to discuss for the next several TLC's.

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TECHNOLOGICAL LITERACY: A POLITICAL AND EDUCATIONAL CHALLENGE

Robert A. Roe

Thank you very much for your generous introduction. You know when you're the first speaker, it's the most difficult spot because you have to wake everybody up, set the tone, and then hopefully, get some ideas across about some things you want to say.

If you think it was tough getting up early to get to the conference this morning, I have to tell you a story. I had to give a speech to a scientific group last night and I went to bed a little late. In my sleep, I was thinking and dwelling on some of the things I'd be talking about this morning. All of a sudden I hear clang, clang, clang. You know when you're in that sort of fog of sleep, you're not sure what is happening. Then I realized that the fire alarm had gone off. So while you were busy resting and getting ready for this morning's program, I got up, I guess it was about 2:00 o'clock, ran down the back stairs in my hotel down to the street. It was very cold. Two hours later, we finally got the fire out on the fifth floor and I was able to get back to my room. So, I want to thank you for inviting me and tell you that I was probably up earlier than anyone here.

Now, why am I here this morning? The idea is to explore how we get something done. When Rustum got in touch with me and invited me to participate, he sent me some data. I looked over the data and I said to the people on my staff, this is something we want to participate in because I think it's an area where we can make a contribution. It's a place where we can get some real interchange going. In the literature that was forwarded to all of us on the program that Rustum had prepared, it was stated that the average citizen is being gradually disenfranchised by his or her own technological illiteracy. Increasingly, decisions are being made neither by citizens nor their elected representatives, but by technical experts mediated by special staffs, and then colored by the cultural biases of a sensation-oriented press.

I'm delighted that this Third Conference on Technological Literacy is not just a conference of educators or politicians or of business people. Instead it is a conference based on the recognition that we need to put all these people together in order to accomplish something. So I want to compliment Rustum in putting together this group. I am certainly pleased to be collaborating with Dr. Selby and Dr. Baker who are also participants on this introduction panel this morning. In addition, I want to compliment Rustum for the effective and insightful testimony he has offered on so many occasions before the Science, Space, and Technology Committee.

Our theme today, technological literacy in a democratic society, aims directly at the future of our country. We are talking about the dreams, the hopes, the aspirations and the very freedom of our nation's people.

Among us there are those who are philosophers of doom and gloom. They choose to spend their time and efforts in dwelling on the decline of the United States as a world power and a world leader. Also, so many published accounts report only from a negative point of view. The country is declining; we're not what we were; there isn't the energy.

There isn't the enthusiasm that there should be in our people. Fortunately, however, there are far more of us that look to the future as eternal optimists, excited at the opportunity to participate in the adventures of tomorrow. I wish you could share my job with me and be aware of all the new and exciting things that are happening in our universities, research institutes, and laboratories.

Rustum spoke a little bit about the super collider and superconductivity, and what is going on with the space program. There are important questions to think about in each of these areas. What do we envision for the Space Station? Should we go to Mars? What else should we be doing? What a wonderful opportunity the people of America have given me to head up the Science, Space, and Technology Committee which is dealing with all of the tomorrows, the hopes, and the aspirations of our nation and our people. I happen to have a deep faith in the spirit, the resourcefulness, and ingenuity of the American people.

You know, every politician that runs for public office seems to talk about a new frontier of one sort or another. When we speak of super colliders and superconductivity, the new frontiers are in science and technology. But in reality, the new frontier truly resides in the American people themselves, and especially in the minds and spirit of our children and our young adults. Secretary General Mikhail Gorbechev has written a book called Perestroika, or restructuring. If you haven't read it, make it a point to do so. I haven't completely finished reading it myself. I must admit that it took me a little time to get into it, the first couple of chapters. But five or six times as he speaks to the restructuring of the Soviet Union, he speaks of science, space, technology, and education. He links the four together as part of the basic theme of the restructuring of Soviet society, the whole educational and economic vitality of the Soviet Union.

Now, we might ask ourselves, why are we gathered here today for a conference on technological literacy? We are here to learn from each other, to hear and listen, but most important not to talk at each other. And then equally as important, to do something about it. I've been to dozens of conferences, hundreds of them to be more accurate. A conference has to have a goal, a place to go, some decisionmaking, a direction for policy. In that process, we have to take a retrospective look first, and ask ourselves, where have we been? Then comes, where are we at? And finally, where are we hoping to go?

Let me share a point with you. It's only twelve short years to the year 2000. Everyone speaks about the 21st Century, but it's only twelve years away. I hope the good Lord preserves me long enough, and with enough energy, to appreciate that exciting time. We should be thinking in terms of a "Renaissance" for this nation in the new century. You could say the renaissance of our American democratic system, of our American way of life. And from a personal standpoint, I would say that it would be a rebirth in the productivity of the individual and an examination of the quality of his or her life. What role will that individual play in the nation and the society? What will that person do with his or her life? I am referring to the recognition of the whole person, literature, music, the totality of that individual in a civilized community.

Today, we're surrounded and almost inundated by signals of change in our position as a nation. And those that can't see that are blind. If you think it's difficult to be an educator, try being a public official today. Perhaps the toughest job in that respect is being a mayor in America.

So, what's happening to us as a nation? What can we see? We've got a global economy. There is no longer going to be a situation in the history of mankind and womankind where there's not going to be a global economy. That is a fact of life. All of the trade bills and all the Japan-bashing and everything else that goes on is not going to solve anything. It is a global economy and we have to recognize that the world has shrunk to the size of an orange, if you like. The idea is that we are one and the same whether we like it or not.

We're living in the new world of instantaneous communication. In the last 15, 18, 20 years, we have transformed the world by our capability to communicate instantly. No matter what happens any place in the world, satellites allow us to hear it and view it immediately. The American people actually participated in the Vietnam War through this instantaneous communications. They saw it happening.

The next change that we must face up to is America's enormous trade deficit. There is aggressive competition among the world's industrial nations. It will never slacken; it will only escalate. The trade deficit tells us that America has to take another look at its productivity capability and quality of its goods. How many of you drive an American car? I can't buy a foreign car because they'd impeach me -- I wouldn't be able to get elected again. But you can afford to do that. Is that being hypocritical? No. When you're looking for a car, you want the best buy for your money.

Now we come to the new political buzz word. The word is competitiveness. Do you know what competitiveness means? Don't feel bad. Of the 435 Members of the House of Representatives, if you asked each one of them what that word means politically or intellectually, you would get 435 different definitions. And the same way with the Senate -- you'd get a hundred different definitions.

What does all of this have in connection with the mediocre to low test scores of American students in science and math compared to the scores of students in other nations. If we're honest, it's more than just science and math scores. We're fighting functional illiteracy in many places. In a little blurb on the TV the other night, they were talking about the rehabilitation of prisoners and the educational level of people who are incarcerated 3, 4, 5 years. The interesting and frightening point was that at least 2/3 of the prisoners were functional illiterates. The crucial question was what was going to happen to these people when they were released.

I have college interns that come to serve in my office each year. I haven't had one bad intern since I've been in Congress 20 years. But let me tell you something. I have to teach them how to spell! Some are working on masters degrees, some on doctorates, and we have to teach them how to spell and how to write a letter. We have to teach them the impropriety of describing the whole transportation system in northern New Jersey when someone writes to complain about having to wait in line because the port authority's toll-collecting areas have a problem that ought to be improved. Why are they talking about the whole transportation system when that's not what the citizen asked? Functional illiterates with masters and doctorate degrees.

We need to look at how these vast changes within our nation, and to our national position, relate to each other. You know, you hear people scream and yell about the men and women in Congress -- the 535 of them that represent the 230 million people in this country. Every decision that representatives make, every decision they don't make, determines a priority. This then becomes a policy direction. Can we afford to spend 4-1/2 billion dollars to build the SCC? Can we not afford to do so? We need to decide what our priorities are. Will we make that investment? How do you measure that against new housing in Philadelphia? When we ask these questions, we'd better well know what the goals of our democracy are, and how we plan to meet them.

How should we be thinking about superconductivity? You know what the Japanese are doing? They're not doing as much research as we and other nations are doing. But they're doing something equally as important and maybe more important. They're figuring out how they're going to set up the mechanisms institutionally to be able to exploit the knowledge and to use it and put it in the marketplace. These are the kinds of things that when we talk about decisions made by the Congress, we ought to be considering. In the 21st Century, like at all other times in the history of civilization, new knowledge and new technology will be the things that change the direction of the world.

You know, at the end of World War II, the United States rebuilt the economies of Europe and Japan. If you were in Europe during the war as I was as a young soldier, you saw devastation every place you went. There was nothing. The great engine of the United States put that back together. And now interestingly enough, some 40 odd years later, we are in competition with Japan, and Western Europe, in knowledge and products.

I talked about the idea of instantaneous communication a moment ago. Television has been a major force in our lives. I remember how that started. People began gathering around a tiny black and white set that someone had. It was a new way of communicating. And then in July of 1969 we could see American astronauts walking on the moon. Oh, and then we were foolish enough to throw away the rocket capability that got us there.

Now what about changes historically in education? In our early history, only the landed gentry had the opportunity to go to school. They would not only learn to read but they would learn French. They would learn about music, about the opera. What a tremendous opportunity that was for people to improve their quality of life, to develop the whole person. Then came the vast waves of immigration to our shores looking for freedom and opportunity. We developed a universal educational system, and it worked. But what we are faced with today is the perspective of an educational system suited to an era that's over. We are no longer operating in the 40's, the 50's, or the 60's. Those times are gone. It is a whole new world out there. And it will be a whole new world. The question is, can we develop an educational system that's going to be suited to the new era, the era that's developing now and that will extend into the 21st Century, 12 years away.

We must ask what we want our educational system to accomplish for our nation as a whole and for its citizens as individuals. An educational system must provide us with a workforce that enables the nation to grow, compete and prosper. The system must prepare individuals to make their way in a technologically sophisticated society. The system must produce a level of technical intelligence and judgment in individuals that can help them direct and guide policy decisions. We should not have to be making all decisions alone as elected members of government. That's part of your responsibility too. We need the direction and guidance.

We have a veritable "Catch 22" when on the one hand you need to encourage more students to take more science and math courses, and on the other hand you don't even have enough qualified teachers to instruct the current component of students in those courses. It is increasingly apparent that part of our task in rethinking basic education in America is the need to redefine the role of the teacher in American society.

Teachers engage in the finest endeavor of civilization. Our society ought to treat them with commensurate respect. Most of you out there, as the teachers of today, are the architects of what this nation will be in the 21st century. As a society, we'd better hasten to give you our most focussed attention and our most abundant resources.

In America, we have developed an unusual and, I believe, detrimental dichotomy about our teachers. We separate those who teach at our universities and colleges from those who teach in our elementary and high schools. Both groups are in the business of educating a nation. We should view them as participants in a common endeavor. They should view themselves as interrelated and interdependent.

University professors could benefit from knowing how and what students are taught before they come to institutions of higher learning. They could also serve as special resources for specific projects undertaken in the lower schools. Elementary and secondary school teachers could expand and enhance their subject matter knowledge by having access to the university's most current information and research in a given area.

No matter where a college or university is located, it is simultaneously based in one of the nation's 15,300 public school districts. There should be a natural circle of influence and interchange among that college or university, and the surrounding high schools, and elementary schools. There should be a continuous traffic of students and faculty among the various sites. In our task ahead we must learn to make use of every available resource and reservoir of expertise. The final beneficiaries will be the individual students and the nation as a whole.

We ought to stop and think about why anybody would want to be a teacher in today's world. (For that matter, why would anybody want to be a politician.) In my State of New Jersey, my niece is a teacher in an inner city votech school. This school's tough, she's tough. She gets paid $18,000 a year and she's got a master's degree.

In my Congressional District, there is a school principal, of East Side High School in Patterson which is my key city, whose name is Joe Clark. You might have read about Joe Clark in Time Magazine. I know Joe well. He's a tough guy. And it says on the heading of this Time Magazine, "Is Getting Tough the Answer?" He didn't want to allow the drug users into his school. He insisted that this was not going to be done so he closed and bolted the door, and he kept them out. The citizens came back and said you have to provide freedom of access. That is a Constitutional right. He was trying to save the kids. He expelled 60 students. Why did he do it? Because they wouldn't participate in a civilized society and they wouldn't work. Either they were going to run the school or he was going to run the school. If you notice in the picture he has a baseball bat. That's not for kittens, I mean that. Of course, he'd wind up in jail if he used it. Finally they had to battle with the Board of Education and others who tried to keep him off his job.

Last year, as the heir-apparent to the chairmanship of the Committee on Science, Space, and Technology, I thought to myself, I've been in Congress 19 years and now I'm going to take on a new task like you would take on the presidency of a new college. While I was contemplating this new role, the first people to get in touch with me were a group of academicians and leaders in education. They wanted to get together for a small dinner in someone's home in order to get acquainted. I said, sure, I'd be glad to do that. There were about seven or eight people at that dinner. I listened to them, and I was distressed. They talked about education. They talked about math and they talked about science and technology. I continued to listen. You learn by listening. Then I said, let me ask you something, I'm puzzled. We went through a little bit of dissertation on the math situation, what we should teach our kids technologically, what should be in the schools. Then I said, why don't we go ahead and just do that? What are we waiting for? We don't need a revelation to start. We know that it's not taught properly starting in the first grade. Small children can operate Atari toys before they start school. They know more about computers than their parents because their parents are afraid of computers. If you give a child a computerized toy, he'll run it just like that. He can take it apart and put it back together again at three years old and four years old. It's the truth. When I said to them, let's just go ahead and do all the things you mentioned, they said you don't understand Congressman. We can't just do that. We'd have to change the mores of the tribe first and it would take generations. I said, "Let me tell you something. If I were governor of my state, I would call in my educational commissioner. I would tell him that in 30 days I want that level of education in my first grades and I'd have that or he wouldn't be commissioner in my state." That's what I would do because I think it's basically that simple to get it started. You don't have to make an amendment to the Constitution to do it.

Let me finish now. I talked about the teachers for a while. Let me say something about what it's like to be a politician. If you are a liberal, you are a leftist. If you are a conservative, you are a rightist. If you are Republican, you are anti-people. If you are a Democrat, you are a big welfare spender. If you go along with the party leadership, you are a political hack. If you don't, you're labeled a maverick. If you vote with the majority, you're a rubber stamp; and if you don't, you're independent and unreliable. If you try to please the people, you're a demagogue and if you don't, you're a poor public servant. If you aspire to higher public office, you are an ambitious opportunist. If you don't, you have no brains and no ability. If you get notices in the press, you're a publicity hound and headline hunter and if you don't, you're a do nothing public official. If you speak up and express your views, you're a show-off, and if you don't, you aren't aware of what's going on. Nobody said it was going to be easy to be a teacher or an educator. Nobody said it was going to be easy to be a politician. But just think if we can get this coalition together. Between the educators and the politicians, each teaching the other, then maybe we can select the new direction for tomorrow that's there to be taken. And come the year 2000, twelve years from today, we would be completing our 14th or 15th conference at that point, we'll be able to extol the virtues of what we've been able to achieve. Together we can redirect America in the direction it should go.

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BIG NEW IDEAS -- WHERE ARE THEY TODAY?

Robert Rodale

Ideas can be judged or categorized in four ways: The first is quality. You can ask whether an idea is good or bad. Or whether it is primarily suited for use in good or bad ways. Second, ideas can be categorized by subject. Some apply to one area of human culture. They are used primarily by members of one profession, or a sharply defined group of thinkers or workers. For example, the idea of deconstruction is a form of literary criticism. Existentialism is a philosophical idea. Quantum mechanics is part of the theoretical foundation of modern physics.

A third way to categorize ideas is by their age. Some are new, like the concept of chaos. Others, like monotheism, date back to antiquity. Then there is size. Ideas come in different sizes. Some are small, other medium-sized, and a few are big.

The big ideas reach well beyond a subject area. They may originate in a discipline, but almost immediately begin to influence thought and action in other areas. Big ideas not only spread beyond the confines of a subject area, they eventually become the glue that lets people link smaller thoughts into a generally understood approach to life.

Our culture is built of ideas of quite different size. We use many small ideas. Another group of ideas uses ideas of medium size, and we rely on relatively few big ideas. All good ideas -- regardless of their reach or scale -- are by definition of value. But if a culture has invented and is using many small ideas, but lacks a flow of new big ideas, it may begin to go stale. And eventually to weaken. That is my premise.

We are in that situation today. There are available for our use a certain number of what I call big ideas of general usefulness. But we don't have enough new and fresh ones. Our thinkers are increasingly grouped together in tightly-knit bands, working in specific subject areas. They are being taught to invent and use small ideas. New big ideas are being generated slowly. Why? Because our culture lacks sufficient free spaces for general thought.

That, essentially, is my argument. I will begin to develop that argument by putting forth for discussion examples of ideas of various sizes. Because much of my work is in the area of productive use of the land, I will select as examples ideas rooted in agriculture and the care of the natural environment.

A small idea first.

Some plants can send powerful messages to other plants. Farmers have known about that effect for centuries. The value of crop rotation is based to some extent on the chemical messages that one crop can send to another growing the following year. And especially the power of some crops to exude chemicals that discourage weeds in following crops.

Oats have that power. Forty years ago on our farm we grew oats in the rotation to reduce weed problems in other crops.

Science in recent years has identified and measured more precisely plants' abilities to influence other plants. And the effect itself now has a name -- allelopathy. More than that. Allelopathy has become an idea. Agricultural scientists now use it along with other ideas for weed control, like cultivation and use of herbicides. But as useful and powerful as allelopathy is, I classify it as a small idea. Agronomists and weed scientists use it. Some farmers use it. But many agricultural scientists still don't know about allelopathy, nor do they have reason to use it within disciplines like post-harvest technology or food processing. Allelopathy is likely to remain powerful within a rather sharply defined area of knowledge and application.

Now for an example of a medium-sized idea.

Environmental Restoration is interesting to think about. The idea that a natural idea that has been degraded or even destroyed can be restored. Rivers and streams are being restored. So are prairies and some forests.

What is restoration? It is a series of informed and deliberate human acts aimed at causing a degraded natural area to return to its original condition. A good idea, and quite useful. Books and articles are being written about restoration. About a month ago Time Magazine ran a two-page article about the restoration movement. We are all enriched by the thoughts and actions of the restorationists.

How big is environmental restoration as an idea? I put it in the medium-size category. Medium because it requires multi-disciplinary research and combined action by people with a variety of kinds of knowledge and skills. But still somewhat limited in total area of application. Even though restoration is an extremely valuable idea, it does not reach out into all areas of thought and action. Conservation is a big idea. Maybe not the biggest of big ideas. But still definitely in the big category. And we can easily trace its history.

The word conserve was first used in the 16th century, to mean preserve. The word conserve later described a store. We are probably all familiar with fruit conserves -- a jam made to avoid the waste of fruit. And in an environmental sense, the word conservation began to be used in specific situations in the late 19th century.

Then early in this century, Gifford Pinchot created the concept of a conservation movement. Pinchot also gave to conservation the status of a big idea of general usefulness. He describes that process of creation in his autobiography, Breaking New Ground. "At the beginning of 1905, when the Forest Service was created, the twenty-odd Government organizations in Washington which had to do with natural resources ... were all in separate and distinct watertight compartments."

They were the Agriculture Department, the War Department with its Corps of Engineers dealing with floods, stream flow and inland navigation, and finally the Interior Department, which ran the Geological Survey and the General Land Office. "It was a mess," Pinchot wrote. "A mess which could be cured only by realizing that these unrelated and overlapping bureaus were all tied up together, like the people in a town. The one and only way to bring order out of this chaos was to supply a common ground on which each could take its proper place, in cooperation with all the rest."

Gifford Pinchot rationalized the confused natural resource use problem by creating a new big idea -- conservation as a movement. Not just conservation of fruit by making jam, or conservation of water during a shortage, but conservation as a unifying and powerful big idea of general usefulness. He even tells us exactly where and how the idea came to him. Not far from here, as a matter of fact. In Rock Creek Park, "in the gathering gloom of an expiring day," during the winter of 1907, on the back of a horse named Jim.

He was riding on Ridge Road, "taking his problems with him." Then it happened. "Suddenly the idea flashed through my head that there was a unity in this complication -- that the relation of one resource to another was not the end of the story ... all these separate questions fitted into and made up the one central problem of the use of earth for the good of man."

The rest, as has been said many times, is history. A world movement is born. That's what Pinchot called the chapter in which he wrote of the genesis of that big idea. And it was a broad movement, touching first forests, but then agriculture, public health, mineral use, industry, waste disposal and parks. Almost everything people have done and thought about since 1905 did or could draw inspiration from the conservation concept.

Conservation caused great things to happen for about 30 years. It is still causing a few good things to happen. Energy conservation is still promising and necessary. But in the broad sense the idea of a conservation movement is old and tired. The word itself no longer causes our hearts to beat faster, as it once did. The blind alleys and dead ends are too visible.

Look at the Soil Conservation Service. It was created as a maker of bandages to place over the open wounds on the land created by agriculture. But many are failed bandages. There is more erosion of soil today than ever before. And the most effective erosion preventive -- conservation tillage -- requires the use of vast amounts of herbicides to control weeds. The very herbicides that are now seen as one of the most serious of all environmental problems. Laws are being enacted to restrict or eliminate their use.

Big ideas of general usefulness have a life span, just like people. Or like industries. They are born, grow, mature, and eventually die. At some point in their life span they are more useful than at other times. And they can revive, and return to youth if conditions change. The invention of non-polluting herbicides might revive conservation, and reinvigorate the Soil Conservation Service. Or maybe agriculture will change fundamentally, allowing farmers to farm in new ways that actually make the soil better rather than worse. Then the idea of conservation, as applied to agriculture, could become totally obsolete.

Examples of Other Big Ideas of General Usefulness

I have been thinking about big ideas in this specific way for only a few months. But already I have filled seven or eight pages of a small notebook with examples. And almost all of the big ideas that pop into my mind share with conservation the close association with one person -- often the originator of the idea.

Here are some ideas from my list, with the names of people associated with them:

Natural selection and evolution -- Darwin
Communism -- Marx
Christianity as a religion -- St. Paul
Mass production -- Ford
Holism -- Smuts
Psychoanalysis -- Freud
Sanitation -- Lister
Chivalry -- (the mythical) King Arthur
Entropy -- Carnot
Temperance -- Amy Semple McPherson
Quality in manufacturing -- Deming
Revolution -- Copernicus
Paradigms -- Kuhn
Existentialism -- Sartre
Structuralism -- Levi-Straus

At least one of those big ideas -- chivalry -- is probably dead. Temperance does not have much life in it. Communism seems to be on the decline, but that could change. Interest in quality is very much alive at the moment.

Existentialism is at the very least out of fashion. And Claude Levi-Straus now renounces structuralism -- described in the December 21, 1987 New York Times as "the search for underlying patterns of thought in all forms of human activity." Levi-Straus now says the term has become "too ambitious in the claims made for it."

How do ideas get on my list? What characteristics differentiate a big idea of general usefulness from smaller ideas? Ideas must pass a series of seven tests to convince me they are big:

1. Usefulness. The idea must be useful. That doesn't mean the idea has to be used primarily in good ways. At this point I'm trying not to get tied up in an effort to make value judgements. Usefulness is enough for me.

2. The idea must be general, or at least appealing to generalists. That's the whole purpose of big ideas. They are of general usefulness, and can give those generalists who understand them an advantage over specialists.

3. Big ideas must exist in both an abstract and a practical sense. They have to be able to fill a spectrum ranging from theory at one end, to specific practice at the other.

4. Be of at least some interest at all levels of human concern with ideas. Big ideas should not just appeal to leaders and makers of policy. They should be grist for teaching to children, and for use in the household.

5. Big ideas are geographically and culturally extensive as well. They are or can become significant themes in life in both East and West, North and South. You find them in homes in primitive cultures, and in apartments along Park Avenue.

6. True big ideas can't be encompassed or confined within one academic discipline. Nor do they spring from one limited area of human activity or thought. They are pulled out of intellectual soup cauldrons.

7. Finally, they must not be of one moment. Big ideas are not the theme of the month, or the concept of the year. They have life over an extensive period of time. Yes, they can die or fade away. But usually they last for more than a generation. Often big ideas remain current and useful for many generations. And as I said earlier, big ideas can recede in importance, and later come to the forefront again.

If an idea passes all seven hurdles, it enters the category of big ideas.

Regeneration -- Case Study of One Big Idea

I have been working for 7 years with one big idea, which I call regeneration. I don't mean regeneration in the sense that a salamander can regenerate its tail. Or that some insects can grow new legs. My conception of regeneration begins with the observation that all living systems have ways to respond constructively to disturbance. When they are shaken up in some way, they tend to respond by recovering and often improving beyond their pre-disturbed state -- regenerating. And if a living system is part of a production system, we can use regenerative capacity in practical ways.

I am going to tell about the origin and nurturing of the regeneration idea in order to attempt to show how big ideas need big areas of thought and action in which to develop. And again I am going to use agriculture and the use of natural resources as an arena for discussion, because that's the original area of my experience and work.

Regeneration has become the central theme -- the big idea -- around which much of my work centers. We got started with that idea by thinking about how eroded and wasted land gets better when allowed to rest. Modern farming methods often tend to reduce the quality of land over time. Erosion takes place. Soil structure deteriorates. When those processes so weaken land that it can no longer support profitable farming, the farmer leaves and in effect gives the land back to nature. Then the land begins to recover. Some land improves quickly. Some takes many years to overcome abuse. But almost always land in the care of nature regenerates.

My idea was that the regenerative capacity of land could be studied, and put to practical use. Our goal became to begin to learn exactly what processes occur when land in the care of nature regenerates. We observed specific regenerative tendencies. Such as the proliferation of perennial plants in regenerating land. The increase in the number of leguminous (nitrogen-collecting) species. And the fact that the surface of land in the regenerating state is covered with plant material, protecting it from erosion.

Then we set out to modify agricultural production systems in ways that build into them regenerative tendencies. We wanted to give to farmers the same kinds of tools that nature uses to regenerate land. We would not accept reduction in the level of production to achieve that goal. In fact, we felt it would be possible in time to increase production. And in the short run we strove to reduce the use of inputs such as fertilizer, pesticides and energy, in order to cut costs and increase profitability.

The idea of creating a regenerative system of agriculture was first articulated in 1981. Although at first our work with regeneration was limited to agriculture, the idea of regeneration quickly began to show that it had within itself qualities that would not allow it to remain in the small or medium category. To explain the first stage of the growth of regeneration into a big idea of general usefulness, I need to return to a discussion of conservation and its relation to agriculture.

Conservation and agriculture have until recently been two separate and distinct ideas. And two different methods. Agriculture is the idea and the method of production of food and fiber. Conservation is the idea and the method of protection of the resources used for that production.

Agriculture has a long history of wearing out land. Conservation has a much shorter history, and lately not a terribly good record of success. Over the past 20 years the idea of "conservation agriculture" began to take shape. As I have pointed out, the first techniques of conservation tillage required large amounts of herbicides. They created some undesirable side effects. But there is wide agreement that the process of attempting to combine conservation and agriculture into one method is a good idea. And I think it's a big idea.

Regeneration amplifies the usefulness of that idea and makes it still bigger. It suggests the inevitability of a complete marriage of conservation and agriculture. In regenerative food production systems there are no real distinctions between conservation and agriculture. They are fused into one idea that is bigger in scope than either.

But that capacity to fuse conservation and agriculture into one bigger idea has proven to be just the beginning of the expansion of the regeneration concept. Within a short time it became apparent that regenerative agriculture used regenerative techniques and specifically regenerative types of technology. That opened a fascinating conceptual door. There seems to be no reason why regenerative technologies and techniques could not be invented and used in other areas as well.

Regenerative technologies allow people to make better use of the internal capacity of systems and resources. They not only conserve value and energy, but are aimed at giving new life to the resource base.

Repair is a regenerative technique. An item that is repaired effectively is given a new lease on life. Invention of better repair methods is one example of work on regenerative technology.

A regenerative agricultural technology is the improvement of perennial grain-bearing plants. Almost all present grain plants are annuals. Because they often require tilling, soil used to grow them is subject to erosion. Perennial grain plants keep the soil covered for many years. And in addition, their vigorous root systems are regenerative of soil structure.

Regenerative techniques are now also being used in community development. Several towns in the U.S. have designated themselves regeneration zones. Residents of those towns search systematically within themselves for the ideas, skills, information and local resources that can be used effectively for improving community well being.

Another area of work is the development of regenerative techniques of management of organizations. That includes specific studies of the internal resources of companies, as well as regenerative methods of training -- teaching people how to enhance their internal resources by cooperating more effectively with co-workers. To the best of my knowledge, several hundred thousand people in the U.S. -- and some in other countries -- are now conversant with the language and the concepts that allow them to use regenerative techniques effectively.

My purpose in explaining the regeneration idea to you in this brief way is not to argue that it is a good idea. I think it is, but that's not the issue. I present it as an example of a new big idea. We know the origin of the idea, can see its path of development, and can measure the extent of its application. We also can look at the role of American universities in the origin and nurturing of this idea.

Are Universities Good Places to Work on Big Ideas?

Pessimistic views of the university as an institution which fosters great thinking are fashionable today. Like many others, I have read The Closing of the American Mind by Bloom, and The Last Intellectuals by Jacoby. But I am optimistic. I believe that universities still can be places of innovation. They have, to use one of my favorite phrases, tremendous regenerative potential. True, universities have hardened into a disciplinary pattern that causes people to work in ever narrower areas in order to gain tenure and to advance within their field. And it is also true that many university researchers are working to shed light on portions of big ideas that were originated many years ago. Some of those ideas have lost much of their relevance. But I feel that if ways can be found to bring people in universities into contact with emerging big ideas of general usefulness, and show them the practical uses of those ideas, the situation can change.

If we look at the origin of previous big ideas of general usefulness, I believe we see that many originated either outside the university environment, or at the point where higher education was about to take on a new challenge, or move into a new area.

That happened with conservation. Gifford Pinchot was the first professionally-trained forester in the U.S. He had to go to Germany for his education, because no schools of forestry existed in the U.S. then. He participated in the creation of forestry education here, and invented conservation in the process of doing that.

My feeling is that today conservation is losing much of its steam and its relevance, because the challenge facing us has changed. Our need is no longer to conserve vast resources, but to regenerate the many kinds of resources which now and in the future must carry a much heavier burden of production. We have to create new ways to make our resource base better and more resilient.

Not only do natural resources need regenerating. So do social, economic and political resources. And, I might add, our education and research resources could benefit from regeneration as well.

How can we find the path to that regeneration?

My thinking -- and as I said earlier I have been wrestling with this challenge for only a short time -- focuses on the creation of new kinds of relationships between universities and the rest of society. Let's consider first the relationship between businesses and universities.

Today, businesses are limiting the capacity of universities to invent and nurture big ideas of general usefulness. They do that by putting ever-increasing amounts of money into very specific programs aimed at achieving narrow goals. That situation might be changed if at least part of the support of businesses for university programs were structured in an approach similar to a political action committee. But instead of banding together to support candidates or political positions, businesses would group a portion of their funds to support universities interested in creating free spaces within them to deal with big ideas of general usefulness.

What would those free spaces look like? I believe they could grow out of today's Science, Technology and Society programs.

My experience with the STS program at Penn State encourages me in that belief. Without the encouragement and criticism of my colleagues in that program, some of the most important elements of the regeneration idea would not be nearly as well developed and articulated as they are today. Rustum Roy, who directs that program, encouraged me from the beginning. Ivan Illich provided much useful insight into the spiritual dimensions of regeneration. Larry Spence is presenting a paper at this meeting on regenerative politics. Leonard Waks has contributed much to our appreciation of the psychological implications of the idea. And Patrick Madden, a Penn State agricultural economist, is now on leave to the U.S. Department of Agriculture to administer a newly funded program of support for regenerative agriculture at land grant universities and private research centers.

The original idea of the regeneration zone -- a community motivated to study the resources and the technologies within itself -- was as a laboratory for STS research. A way for members of different academic departments to join in studying the community use of one particular big idea. While that vision has not yet been achieved in total, the communities using the idea exist and are waiting to be looked at systematically.

Much work on the regeneration idea at other universities is building a base that could be and is being used for national and even international work on this idea. Perhaps most important is the work of John McKnight and his colleagues at the Center for Urban Affairs and Policy Research at Northwestern University. They are developing the technique of capacity analysis for urban neighborhood regeneration.

California State Polytechnic University at Pomona is developing an Institute for Regenerative Studies.

And there is now considerable interest in the evolving concept of regenerative environmental education -- presenting the student with a more hopeful view of the environment and inviting his or her active participation in the improvement of the natural and built environment.

In conclusion, I am convinced that there is today a great need for new big ideas of general usefulness. And the potential for the creation of those ideas exists within our culture. They will spring forth and be nurtured and used only if universities create new kinds of partnerships and new kinds of free spaces for thought and study within themselves.

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THE EMERGENCE OF A NEW SYNTHESIS FOR BIOLOGY EDUCATION

Paul DeHart Hurd

The traditional curriculum for the teaching of biology has a format that the work of Charles Darwin stimulated more than a century ago. To illustrate Darwin's concept of the origin of species, Thomas H. Huxley wrote a biology textbook organized as a study of life forms from simple to complex: from amoeba to frog for animals and from protococcus to the bean plant. Huxley's book was published in 1878 and was the first text combining into a single course what had previously been the separate subjects of botany and zoology. The title of his book was Practical Biology, practical in the sense that it was designed to serve as "an introduction to the study of human anatomy and physiology."

Near the turn of this century, topics on human anatomy and physiology were added to high school biology textbooks. Over the years most of what has been taught about humankind has been sacrificed to its parts and the parts have been more frog than human, and man's behavior more ape than man.

Since 1983 more than one hundred national panels, commissions, and committee reports have been published calling for changes in all of schooling, but particularly in the teaching of science. The reports stress the need to reconceptualize and reformulate what a general education in the sciences should mean. The present curriculum stereotypes are viewed as deficient in rationale, goals, choice of subject matter and modes of instruction needed to meet the educational demands for young people who will spend most of their lives in the 21st century. A major criticism of contemporary science courses is that they have become so "watered-down" with thousands of isolated facts that any knowledge of science has been drowned: courses are rich in information but poor in knowledge. The guise for this approach is that it is necessary to prepare students for entrance into a university and for a career in science: the great delusion of science education.

The national reports on the condition of education in the United States call for the teaching of science in a new vein. In response, for a new context for science education and for a new synthesis of subject matter the concept of science-technology-society has emerged. The STS concept represents a more valid interpretation of the structure and ethos of modern science than do the narrowly discipline based courses that now dominate the school science curriculum.

A brief examination of the history of modern science, beginning at the turn of the century, reveals that the traditional disciplines of science -- biology, chemistry, geology, physics -- have been fractionated into over 70,000 different fields each with its own journal to sustain communication between researchers. Today, distinctions between one scientific effort and another are identified by the problem being researched, for example, cognition, fiber optics, laser chemistry, monoclonal antibodies, plate tectonics or super novas. Furthermore, many of the traditional disciplines have been hybridized into new areas of research such as astrophysics, biochemistry, biophysics, molecular biology, geobiochemistry, bioengineering, human ecology and hundreds more. What is now being sought is a higher order curriculum framework that is not only more unified in terms of the

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fields of science but is also rich enough in perspective and subject matter to make it possible to relate science to human affairs.

The recommendation most frequently made in the national reports for the modernization of science education is that technology concepts and reasoning processes be integrated in creating a new science curriculum. The addition of technology concepts is viewed as the best way to bridge the gap between science, society, and how people live, work, and plan for the future.

Technology in the modern sense is recognized as a socio-technical system that enables people to extend their adaptive capacities both qualitatively and quantitatively. Technology is also a process by which information from the sciences, engineering and the social fields is used to change our environment or some aspect of human existence. The thinking skills associated with technological endeavors closely resemble those that individuals need for resolving personal and social problems in everyday life. Technology as an enterprise always involves people, influencing either the way they live, or the work they do, and computers in the future may influence even the way they think.

As a teaching goal science and technological literacy translates into the ability of a student to interpret science and technological achievements and deficiencies in terms of the human and social forces that generate and sustain them. Students who are illiterate concerning the interaction of science, technology, and society are doomed to live isolated from the culture that surrounds them but which they cannot fully experience.

The image of science held by many laymen and teachers is that science and technology are distinct and separate enterprises. Over the last century and a half, science and technology have become mutually supportive not only in terms of research but also in ways that they affect individuals and social affairs. The Nobel Laureate, Robert Oppenheimer, has described the interrelationship of science and technology as "two sides of a single coin." The 'intelligent' instruments that engineers develop make it possible for scientists to ask new and more penetrating questions of nature -- questions that have been unanswerable for the lack of appropriate technology. Consider the contributions the scanning tunneling microscopes are making to research in molecular biology; the linear accelerator to physics and the potential of the supercollider or the laser to research in chemistry.

The impact of the science-technology-society concept on the reform of the precollege biology curriculum has been minimal. A few topics on environmental issues such as the control of air, soil, and water pollution and the effects of radiation receive scattered attention. For the most part these problems are taught from a negative point of view and generate unfavorable student attitudes toward science and technology. What is missed is the entire social and cultural history of modern man that began when he first used sticks and stones as tools for hunting and defense. Advances in technology led to the introduction of agriculture and all it has meant for the ways of mankind, and later the industrial revolution changed how and where people live and work. And as we face the next major revolution in human history -- dubbed the 'information age' -- we are suddenly aware that science and technology have rendered Darwin's concepts of natural selection and survival of the fittest obsolete, and that humankind is now responsible for its own evolution and survival. Whether mankind or an individual survives depends upon the wise utilization of knowledge.

A major reason why the STS concept has not made significant inroads into current biology curriculum is that the context of courses and textbooks is narrowly discipline bound. Except for updating particular topics and changes in emphasis, for example DNA and heredity, less on taxonomy and more on ecology, curriculum themes are much as they were in 1900. What is required to make STS a viable part of biology teaching is a curriculum context that centers upon humankind.

To accomplish a human biosocial curriculum will require that we bring together into a unified perspective what has been separate in the study of man. This means fields of research that study humankind must be searched for integrative concepts: human anatomy and physiology for biological characteristics; plant and animal ecology for principles that contribute to an understanding of human ecology; psychology for concepts of individual behavior; sociology for insights into group behavior; anthropology for an understanding of man's history and culture; medicine for information about how the human organism can achieve optimal growth, development and longevity. Once these concepts are identified the curriculum developer has the task of integrating them to form a coherent picture representing the whole of man.

The conceptual scheme for the new synthesis of biology is to view the human species as a part of nature, our own nature and all of nature. The purpose is to enable human beings to live in harmony with both their natural and social environments. The emphasis in teaching centers is on the realities of human existence, the realities of society, human adaptability, cultural imperatives and alternatives for the future of human beings. A valid description of human evolution requires an interactive consideration of the biological and cultural history of the species. Culture is the uniqueness of the human organism that distinguishes it from all other living forms.

The proposed human context for the teaching of pre-college biology raises the curriculum to a higher level of meaning for the student than can be conveyed by the traditional courses. The conventional curriculum is not fully adequate to deal with human beings either as organisms or in terms of human adaptability. The cognitive skills embedded in human biology are more extensive than found in prevailing biology courses. In addition to learning about the inquiry procedures of formal sciences students have more opportunities to gain experience in making qualitative decisions. Nearly all problems of life and living involving biosocial issues raise questions about values, ethics and sometimes morals. Teaching students a particular set of values is not the objective, rather it is to provide students with opportunities to integrate their knowledge of science and technology into making informed judgments on real-life problems. Information alone is not sufficient for dealing with human experience.

Some individuals question whether this approach to the teaching of biology reflects current research in the biological sciences. Research in all fields of science today is largely guided and supported in terms of its possible contribution to social and economic progress, such as the research on cancer, AIDS, longevity, agriculture, genetics, smoking, food values, and optimizing environmental conditions. Thomas Kuhn, the eminent philosopher of science at M.I.T., notes that today both progress in science and the shaping of new fields result as much from social, economic, and institutional forces as they do from reason and observation.

I believe we have passed the point in time when we can justify the teaching of biology entirely for the enoblement of the discipline and its history. We are also past the time when we can justify that a knowledge of sub-human organisms is basic to understanding mankind. The proper understanding of man can never be less than man himself. Now that human beings have reached a time in history when they must assume responsibility for their own evolution if the species is to survive, the teaching of biology takes on new perspectives. Biology today is not the same science as it was even a decade ago, nor are the educational goals of yesteryears suitable for an education in biology for today and the future.

The national reports have made it clear that the United States faces new realities for the present and future and therefore there are new expectations for what education in the sciences should mean for citizens as well as for researchers. It does not seem reasonable that mankind can successfully direct his own future, his own evolution and be ignorant of his own nature, culture and ecology. We must now bring together the sciences concerned with man and synthesize a new curriculum context, and select the subject matter that focuses on the life and living of humankind.

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ENGINEERING AND TECHNOLOGY

James R. Johnson

There is a great sense of need in the United States -- a need to revitalize our production system, to restore our industrial hallmark of efficiency and quality and to compete fully in the global marketplace. In large measure economics governs the flow of trade in a world grown ever more technological, and as a consequence comparative economic advantage is affected by the generation and management of technology. The key element in this episode is people People, who among other things, invent, design, innovate, develop, produce, and market.

These people for the most part are engineers, technologists and tradespeople. I plan to focus on engineers and technologists in this discussion and on the linkages between their colleges or universities and industry that can play a major role in fulfilling the great national need I cited above.

For our purposes here I define technology as the application of knowledge, tools, and skills to solve practical problems and extend human capabilities. It is enhanced by the discoveries of science and shaped by the designs of engineering. Technology is process, although it is often known by its products and their effects on society. Thus it is also social process as well as technical process. Technology has been primarily the responsibility of industry where we find applied research and development, know-how, patents, production and marketing.

The traditional role of colleges and universities is to impart knowledge, or generate and diffuse new knowledge, and to hone our sense of responsibility to contribute. But, is it not appropriate that at least some of our colleges and universities contribute more directly to the generation and management of technology? Technical schools may give more or less emphasis to various subjects within a technical spectrum, according to the nature of the school. The subjects will range through crafts, trades, technology, engineering, applied science, and basic science.

At present several of the large government agencies require that proposals from the big research universities show in their plans how they will transfer to industry the technology to be developed in their programs. The problem is that the research universities don't do technology. They do science. They can't transfer what they don't have. I believe this is a very important issue. Certainly we need to develop more effective ways to transfer into the hands of the technology generators the new science developed or developing at our research universities.

With our present incentive systems this is much easier said than done. In the research universities it is basic discovery and new science that is sought after and rewarded. The incentive system further rewards the publication of this material in elite scientific journals. It does not support the hard work of translating research results to the engineers and technologists in the industrial system. Further, it is not surprising that the sense of responsibility to do so is not foremost.

Engineers graduated from this culture of science will be biased toward the science end of the spectrum. They will sense that discovery is more valued than innovation, design and application.

I would not propose, however, to convert the research universities into technology schools. It would likely be impossible to do so and furthermore, the United States needs to continue to support its strong basic research institutions. Rather, I suggest that 1) we develop more effective means and incentives for translating the results of this research from the big science schools into our technological systems, and 2) that we increase our support for the more technology-oriented colleges and universities and institutes.

Translation of basic research results is difficult at best. Not often is a discovery so obviously stimulating as the recent discovery of ceramic superconductors. More often, the importance of the discovery may be obscure or unappreciated even by the discoverer. There must be people who are alert to the need or can visualize the potential of discoveries who will actively promote their translation.

Early in this century, engineering experiment stations were active in using and translating university science into technology and then through industry to products. Modern translation mechanisms include research parks, their equivalent "valleys", "routes", etc. and myriad centers. Other mechanisms include research institutes, government laboratories, industrial laboratories and ventures. The success for connections between basic university research and the eventual production of goods and services through these mechanisms varies greatly.

Etched in stone over the ivory towers of most universities are the words, "Education, Research, Service." Research universities have a responsibility to serve the public good through their research and education activities. Certainly, long term it is in the self-interest of tax-supported institutions (state and federal taxes) to keep the tax base healthy. In the case of new scientific discoveries this sense of responsibility must be converted into actions that reach to the industrial system where the wealth is generated. This means commitment to the task in terms of stated university goals, incentives for the faculties and staff to so act, and use of mechanisms that will facilitate the translation.

Successful translation across the university-industry bridge also requires substantial commitment on the industry side of the bridge. Industry must refocus to the longer range efforts that are usually required with new discoveries. The tyranny of the bottom line cannot prevail in this case because short term results are unlikely. There must be continuing and intimate interactions among the university and industry people -- heavy traffic on the bridge. All too often in the past industries have established connections and then failed to follow through.

Expectations must be realistic on both sides of the bridge. In general, industry people must not expect to find technology on the university side. Science yes, technology no. A great deal of patience is required, and a willingness to accommodate to quite different cultures. The university people must understand that the free enterprise system is built on investment and profit and that the patent system is a positive value in the overall production system. They too must accommodate.

In addition, I believe that while the big research universities should continue their research and discovery mode making new and stronger efforts to translate their knowledge across bridges, they should also build a commitment to undergraduate students for more involvement in university projects. Hands-on, minds-on activities such as senior research theses have gradually faded out of many engineering curricula. They should be reinstituted. This will require a shift in faculty priorities in the direction of teaching over research, but the overall balance is due for such a change and the university incentive system must respond accordingly.

The second suggestion I have is to give more support to the technology- oriented colleges and universities. This may help generate more technology but more important, it should produce more process and industry-oriented engineers.

The culture in such schools will be biased toward the applied-technology end of the technical spectrum. Technology is process and many have pointed to advanced processing as a weakness in the United States production system. This support must come from the federal government, state government and industry.

The major government agencies must think big (and small) technology as well as big science. It is ironic that in these times of dire need for such support, one huge physics project sponsored by the federal government will dwarf all of the diverse technology projects across the nation. And often, many of the technology schools are not considered for federal government support. The peer review system does not even recognize them.

State government must also give heed to the need for technology-oriented engineering schools. In our area of the Midwest I have seen new engineering programs develop in schools where none existed before. I have been involved with an industrial technology school (4 year) that may be converted to an engineering school. Of course, such new ventures must be done carefully with great attention to goals and to standards. But the need is great and we should move on with these efforts.

There already exist many excellent technology-oriented institutes, colleges and universities in the United States. These should reaffirm their mission and be given greater support as well. I spoke recently with a dean from one such great institution who insisted they had converted to big science. I couldn't help telling him he was going in the wrong direction. I'm sure you'll hear later from my distinguished colleague and fellow panelist about a school going in the right direction.

Finally, industry needs to encourage and use the technology schools. Bridges to these schools may be easier to build and keep busy with two-way traffic. Technology-oriented schools are of special value (or can be) to small and medium size industry. Connections of this kind are especially valuable to economic development and state governments should give special attention to them.

There are, of course, many other factors in the game of global competition and economic health. But none of these can be effective without a healthy and appropriate education system that graduates engineers and scientists who can make the industrial process work.

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GENERAL EDUCATION FOR SCIENTISTS AND ENGINEERS: CURRENT ISSUES AND CHALLENGES

Margaret L.A. MacVicar

Introduction

To the high school counselors of entering students the MIT Admissions Officer wrote: "What we value most in a student is a very solid background in mathematics and the sciences, the ability to read, write, and reason critically, and a healthy and broad interest in those activities and ideas that give individual meaning to life."

Such a prescription is the same as what I believe the nation and the world should seek in its students ... in all of its students, but especially those who aspire to become scientists and engineers. For it is not technicians that we seek to prepare, nor bench-tied engineers practicing narrow specialities and intent on deadlines and objectives devised elsewhere. Our purpose is to direct the best minds toward inquiries and enterprises concerned for the human condition.

Scientists and engineers more often than not are agents or managers of social change. And social change is intertwined with a conception of technology. The nation's undergraduate engineering and science students will come into their adult primes early in a new millennium. More often than not, these graduates will be looked to for good technological judgement, for intellectual rigor, and for social leadership. The graduates' strengths and their weaknesses will, in turn, either inspire the hopes or dash the confidence of others.

I want scientists and engineers of the future to serve well their citizenship in that complex, sophisticated, delicately balanced world, a world of diversity, conflicting expectations, and technologically-driven motivations; a world made all the more precarious by international interdependencies, and by inequities in resource distribution. It is uniquely an opportunity of this age, I believe, to prepare the world's arguably brightest talents to serve well in both technical excellence and in humaneness and basic decency. Out academic programs must look forward to a future where technology and science present dramatic social options and stark choices little imagined only a few student-generations ago.

The Direction

But which way is forward? The task is not merely one of exposing students in the sciences and engineering to more humanities and social sciences, but one of developing a true educational partnership among the technical, arts, social and humanistic disciplines so that on some level students see the interrelationships between science and technology on the one hand, and societal, political, and ethical forces on the other. This suggests, in turn, that these cannot be taught in an isolated, piecemeal fashion by faculty in different disciplines, but that an integrated interdisciplinary approach must be used. One of the challenges of such an endeavor not only will be the education of students but also of its faculty and teachers.

In addition to expanding the social and political competences of our students, we must expand their creative and design capabilities. While relatively little is known about the creative process or the determinants of imagination, there is considerable evidence that the truly creative scientists and engineers are not only broadly educated, but have strong parallel interests in the arts and humanities. There is also evidence that freshmen may arrive more open, creative, and enthusiastic than when they leave four years later from current day sciences and engineering programs. As MIT's Dean for Humanities and Social Science Ann Friedlaender has noted, the development of (1) habits and skills in looking for and assigning analogies, similes, and metaphors in order to permit the juxtaposition of facts and ideas that might not at first appear to be interrelated; (2) the ability to conduct a personal, informal search for new ideas and insights; and (3) the ability to translate findings of this search into the rigorous structured methodology needed for verification, and for incorporation into the accepted body of knowledge, are not the current skills taught to undergraduates within the scientific and engineering disciplines. Subject offerings must be developed that will not only serve to introduce students to a wide range of approaches to knowledge, but will serve to encourage them to make connections, and analogies within a wide range of social, humanistic, and scientific and technical disciplines.

It is timely to think through our educational objectives for the future. For choices have to be made. A choice between continued specialization and the technical density of our leading engineering and science programs, and a broader, more fundamental integration of technical with humanistic studies.

Technology is both a scientific and a social process. My colleague, MIT Professor Leon Trilling, writes of technology that it is "the application of the knowledge of natural phenomena to manipulate the physical and social environment systematically for social purposes."

This view arose from the intellectual ferment in Western Europe in the late Middle Ages and the Renaissance. Within it is the premise that it is appropriate to study nature for the sake of human welfare. As Trilling points out, "From this view is derived that the spiritual and material condition of human life can be improved and that it is commendable to strive to that end." And that, "individuals are free to work out their fate ultimately personally responsible only to God."

Technology, then, is arguably an attitude. Technology encompasses consequences. It carries responsibilities for identifying risk and for weighing human costs against human benefits. Perhaps at no other time in history has the need been so great for leadership and example of social institutions: educational, political, medical, legal, military, industrial. Of these, the greatest leverage is educational.

The Education(*)

What is education? Education and information are closely allied. The term "information" has lost much of its original meaning, however, and in everyday use it is often shorthand for statistics, tables, the pie-graphs. The richness of the word is worth recalling.

Merriam Webster's Dictionary lists:

> Information - (1) the communication or reception of knowledge or intelligence; (2) knowledge obtained from investigation, study or instruction.

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* This section is taken from an article published by the author in Educational Horizons, Vol. 63, pp. 40-44, 1985. (Special issue of Phi Lambda Theta)

Informed - educated, intelligent

Informative - imparting knowledge; instructive

Within these definitions is the essence of "information"; mental rumination, consideration, and interpretation. A process of something going into the mind, and coming out different than when it went in -- involving judgement: weighing, values, analogy.

Let's take an example close to all of us. The data was there, but not the understanding. And no number of individual workstations and thicknesses of printout actually "informed" anyone until too late, it seems.

Each of you has your own horror study about an automobile, I know. But let me comment for a moment on some highlights of my experience for 2 1/2 years, 1977-1979, as a product evaluator for car divisions. You might think that this experience -- a decade ago -- is obsolete and irrelevant to us today. Let's see.

I was given a new car, custom built to order, every three months. My responsibility was to evaluate it for engineering design and performance. Special efforts at the factory and at the regional zone manager and dealer levels were made to ensure quality control so that no embarrassing items should come to my attention. Usually the cars were road driven before delivery to me. I wrote a long letter of evaluation to each division after each car -- in addition to filling in an IBM computer card questionnaire with a dark pencil. In reality, I average a new car every six-to-eight weeks, because of repairs needed. Once I even ahd a substitute car for a substitute car. I was forever shifting maps, flashlight, snowscraper and toolbox to a different car trunk.

One flashy number had large see-through panels that could be lifted out of the roof to give a convertible effect. It was super until I found out that even when the roof panels were in, if I wound down the window in a rainstorm, the roof design had the rain falling four inches inside the door, exactly into my lap.

Once, when I got into a newly delivered car for the first time, just as I closed the door, 2 inches of blue paint flake fell into my lap from the window moulding. The colors hadn't matched well, so they had painted the plastic moulding rather than find another piece.

The worst case was the upscale model. It was electric everything, trunk, windows, dusk sentinel, mugger light, seat adjustor. On three occasions, I flew to New York City for the day and came back to the airport parking garage to find I could not get the car started. The battery was dead. Once the reason was the electric trunk latch, and once it was the electric six-way seat control. The net result was that I kept battery cables in the back seat because when I needed them, of course the electric trunk wouldn't open.

My experiences were not very different than those of the executives provided cars as perks. But the availability of company gas pumps and company-supplied repairs during the day cushioned the inconvenience of poor vehicle quality. No manager should have ignored what the data was saying about the product and service the customer was encountering. The company had data but not information. And theis company was and is not alone in this deficiency amongst U.S. auto companies.

You assert in reply that those at fault aren't scientists and engineers, but managers. Oh, really, I respond. Are these mutually exclusive?

The Aspirational Ethic

Why do almost all whistle-blowing stories involve scientists and engineers as the whistle-blowers, and end with laments about the revenge visited upon them? It is managers who are depicted as overruling them or sanctioning them. And the engineer and scientist as being victims of their own good intentions.

I agonized for Mr. Roger Biosjoly. He and his colleagues at his company, Morton-Thiokol, skirmished for nights, crescendoing That final night before the infamous Challenger launch almost exactly two years ago. Despite the data and despite the unanimous and strong recommendations of the scientific and engineering team, the managers went forward with the launch -- to the tragic outcome known to us all. I'm from New England: Christa McAuliffe was the equivalent of a hometown girl. Ron McNair was my student at MIT: I was on the Admissions Committee that considered his case and on his Ph.D. thesis committee a few years later when we celebrated him.

So was it enough for scientists and engineers to shrug and walk away because they had come to the end of their job description? What kind of society is it that limits technically-educated people to be hired hands? What kind of professional is it that lets himself or herself be boxed into such a job description? Who writes it anyway?

There was a time of independence and glory and dreaming by the individual engineer and scientist. Celebrating a dam -- or a road -- that he or she built. Exulting in the success of a vaccine or anesthesia pioneered by oneself. It was the heady stuff of public service. Of an individual's direct relationship to clients. Of serving the public good. Of being proud of having the public trust.

Somewhere along the line it became instead being a good "company man." Of making a career in a small group within a larger one within a division within a corporation. Far from the client. For profit and sales, not for the social good. And feeling powerless.

Thus, we must re-empower the individual scientist and engineer, rededicate their ethic to direct concern for the public, and reformulate the educational framework of their training to accomplish these.

The New Education

The old paradigm about how science and technology operated in this country, or indeed in the Western world, consisted of scientists and engineers developing technological ideas. And others -- bankers, what have you -- deciding which of these ideas will make it in the marketplace. There is considerable evidence that this classical paradigm of science and society no longer operates. Let me mention some areas in which problems have come up: nuclear power, synthetic fuels, hazardous waste disposal, manufacturing, space launchers, urban services. In all of these areas, technical solutions combined with market forces are insufficient to guarantee community well-being.

Technologists and engineers must be much better prepared to exercise leadership on a full range of issues if technology is to be applied in the public interest. Scientists and engineers should be better guardians of the environment and the workplace; they should be more important participants in the decision-making process in this country.

Education is too narrow in some respects -- certainly not all -- for tomorrow's world. It is essential that we broaden the experience of many of our students in the directions of science, social science, humanities, the arts, and management. There must be a fundamental rebalancing of emphasis in education -- somewhat less emphasis on principles, analysis, and research; more attention to integration, design, synthesis, and implementation.

"So little time, so much to do." How can be best allocate a student's time between the increasing demands for professional education and the demands for a general education that offers a broader range of thought. In assessing the burden on undergraduates, we can see That simply adding house of class time would prevent attention to the quality of student life, the time that a student has for contemplation, for imagination, for putting his or her own head together and interacting with others.

We have a terrific tension here, a tension that is understandable. It should be recognized and dealt with straightforwardly. What we face is the need to reach a consensus on what we want to do. And the consensus must not merely be the common denominator; it must be a consensus that will excite both the students and teacher. Neither will the consensus represent a single vision; we should never fail to allow a separate pathway for the individual scholar.

What are the directions suggested by this line of inquiry. We must move to more engineering and science classroom hours devoted to social sciences and the liberal arts. To a class of admitted undergraduates that share a greater interest in the liberal arts and social sciences for their own sake. To a situation that places a higher premium on self-education. We must move towards a program that permits the undergraduate to have more experience working in a team atmosphere, to work in integrative projects rather than analytic projects.

Further, we should be working on mechanisms that will improve the communications skills, both written and oral, of our students. A major effort is going into developing new subjects that will give students an understanding and appreciation of the human contexts within which science and technology are pursued.

Conclusion

I have an old farmstead in rural Maine. Last summer, an urban, yuppie professional couple vacationed through our area. As luck would have it, their car broke down in an isolated area far from a mechanic. They found themselves sitting morosely by the side of the road in a cloud of steam from a cracked engine block. Being prudent, technologically-sensitive people, they remained stationary rather than risk further travel. After a while, an old pick-up truck came along. A local farmer of an indeterminant age was driving. He stopped the truck and with a half-grunt motioned the two into the cramped cab. My friends got in gratefully and as the truck lurched forward, attempted neighborly conversation.

Each sentence was a new start -- which hung awkwardly in the air, met by silence from the farmer. He kept his eyes on the road, both hands on the wheel, and his mouth shut. Finally, in desperation, one of my friends asked a direct question of the farmer, "have you lived here all your life?" Slowly, the farmers eyes left the road and gazed across the seat. After a few seconds, he replied, "not yet."

Have we, as technologists, toiled in our remote corners all our lives? No, not yet. Hopefully, not any longer. We must strive to develop among ourselves, among our students and in the public at large, an understanding of the fact that engineering and science are, by their very nature, humanistic enterprises.

The message that goes out to school boards, government at all levels, industry, sister educational institutions, and nations, should be that technology offers suggestions of agenda -- of goals and priorities and that attention to human elements and human consequences of these cannot be less than rigorous, thorough and broadly shared. For here is the hard part of being accountable or helping things to grow better, for preserving what is already excellent, and for firmly putting away what is not worthy or is inadequate.

Let me close by remembering Goethe's thinking. We must not be bedazzled by how well something is technically executed -- for even computers do what they do very well. We must always ask what he terms "the essential question:" Is it worth doing in the first place?

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SCIENCE POLICY AND DEVELOPMENT IN THE THIRD WORLD

Michael J. Moravcsik

Overall Perspective

Science and Technology have two distinct dimensions in the context of the developing nations.

The first of these is that science and technology, in the 20th century, are crucial ingredients in the efforts to remedy a broad range of immediate and pressing problems in the Third World, pertaining to the economy, to health, to nutrition, to housing, and to many other main material components of life. These problems are highly visible even to a casual visitor, and are in the main focus of the perception of the Third World in the eyes of the more advanced countries.

The second dimension of science and technology in the developing countries is the task of creating an indigenous capability for these countries in science and technology. Such a capability is essential with regard to all three main roles of science: a) the science-technology-production-livingstyle complex; b) the aspiration of the country to participate in one of the most respected and most influential activities of the 20th century; c) the exercise of the impact of science as a molder of man's view of the world and of man's role in the world.

These two dimensions are, in practice, very much at odds with each other. To optimize the first goal through international assistance, an advanced country might very well turn to doing whatever research and development is needed in its own laboratories, then utilize the results by sending some of its own nationals to the country to be helped to adapt, apply, and implement the results in order to remedy a particular problem. In the process, usually a transfer of hardware also occurs from the advanced country to the one to be helped. At best, such a procedure can show distinctly visible results within a short time.

Unfortunately, this procedure is at best neutral, and most often point blank counterproductive with regard to the reaching of the second goal, namely that of creating a scientific and technological infrastructure in the country to be helped. The transfer of results of research and development, generated abroad, and administered by people from abroad, in no way helps the local infrastructure to evolve, and in fact may retard its development by diverting attention from that task. As an example, the complaint is widespread in developing countries by the scientific and technological community that local companies are uninterested in utilizing any home-grown technology and instead spend large sums obtaining technology, or even worse, technological products from abroad.

The conflict is created by several factors, perhaps the most important of which being the time element. The material problems of the developing countries, as mentioned earlier, are so acute and so visible, that rapid remedies appear to be called for. On the other hand, the stage of development of the local scientific and technological infrastructure (and of their links with the potential users of the results in the country) is usually too rudimentary for bringing this rapid relief to the local problems. Thus the "crisis" is "solved" from the outside, and the country thereby is equally unprepared for the next "crisis" which thus will also be "solved" from the outside.

Clearly, what is called for is some kind of a balance between the two types of activities. In practice, however, the programs of the national and international agencies and organizations are directed predominantly toward the first task. This is not so by default. It is the expressed policy of many of these organizations. Talking to almost any higher level USAID official will provide an eloquent proof of this.

To brighten somewhat the picture, I want to mention, however, one form of international scientific and technological assistance which serves predominantly the second aim, but which is often unnoticed and fails to be included into official statistics on international assistance. This is the education in science and technology students from the Third World receive in American universities. Using the numbers of these students, and calculating the portion of the cost of the education of these students paid for by sources within the United States, one arrives at the noteworthy conclusion that this contribution is around $1 billion a year. It is not the main aim of this discussion to dwell on the details of this educational activity, but we should remember the importance of it and continue to support and administer it in the face of trends and sentiments that would want to eliminate or reduce this contribution.

My aim in the remainder of this discussion is to turn to the analysis of the second of the above aims, the more neglected one, and point at some aspects of science policy that are directly connected with the efforts to create a productive and lively scientific and technological infrastructure in the Third World countries.

The Nature of Science-Building

To set the discussion of science policy into an appropriate context, let me first outline a few general characteristics of science-building which then naturally suggest some elements of such a policy.

Pursuing science is a systemic activity. By this I mean that it is a composite, complex, and sophisticated system, with many elements and linkages which need to be evolved together in order for the activity to be effective.

To appreciate this point, we can look at our own science-making in the advanced countries, but in doing so we need to take an historical perspective, since science has been so much a part of our civilization for the last 400 years in the advanced countries, that many elements of science and of its influence are by now taken for granted and go unnoticed.

The system which the pursuit of science constitutes and into which it is embedded is a large one with many elements. It includes public attitudes toward science, broadbased utilization of science in practice as well in the world view, a productive sector geared toward input from science, an educational system which is conducive to the development of a sufficiently high level and extensive scientific manpower pool, a research network appropriately interfaced with decision makers and supporters, a scientific community with standards, traditions, and practices of its own, a productive sector capable of supplying the tools for scientific work, etc. It is a sophisticated network of elements, interacting with and reacting to each other. It is not an accident that it took decades and in fact centuries for this system to evolve in Europe.

It has been my experience in my contacts with developing countries that the systemic and intricate nature of the infrastructure for science is not well appreciated by decision makers in the Third World. I will refer to this in greater detail in the subsequent listing of some of the consequences of this systemic nature of science building. I want to list five of such consequences.

The first consequence is in the feedback nature of the problems of science-building, that is, the constantly surfacing vicious circles one encounters. Scientific research suffers because the provisions made for science are faulty, and that in turn is due to the insufficiency in the number of people who, through their personal experience with scientific research, have learned how one makes provisions for productive science.

Science education is rote-like and nonfunctional, because science teachers themselves lack a personal understanding of and contact with science, and this defect of the teachers is, in turn, caused to a great extent by the poor science education they received.

Scientists fail to benefit from frequent and fruitful communication with their scientific colleagues worldwide, because they have not had an opportunity to build up their own scientific contacts, which in turn is due to the lack of opportunities for frequent communication. These scientists are not frequently invited to conferences, and hence have a restricted opportunity to exhibit their expertise which would enable them to be invited to conferences.

Links between science and technology are weak because there is no tradition and hence no institutional opportunities to form such links, and such opportunities are missing because there is no tradition for an interaction between scientists and technologists.

The productive sector fails to utilize the fruits of local scientific expertise because not enough precedents have taken place for such utilization to encourage the productive sector to engage in such utilization.

The examples for such vicious circles are a host. The breaking of such vicious circles rapidly is almost impossible. The best hope is in the slow process of making A a bit better so that it can feed back into B, making that a bit better also, etc. This takes time, and in fact defines a natural time scale for significant progress in science building, a time scale which must be counted in the decades, and which cannot be significantly accelerated. Thus patience is needed, coupled with foresight, and these are commodities in particularly short supply.

A second consequence of the systemic nature of science building is that there are no quick recipes for building up the indigenous infrastructure of science. All too often one encounters the perception prevailing in developing countries that science development consists of mastering a few tricks, from which then quickly follows a rapid build-up of science.

It is unfortunate that this misbelief is often encouraged by individuals or agencies from the advanced countries. For example, one such trick is suggested to be the formation of science policy organizations and agencies. I heard, with my own ears once, a fairly high UNESCO official state in public that a good measure of the state of Latin American science is the number of science ministries, councils, and agencies in those countries.

A related, third consequence of the systemic nature of science building is that one must not deal with external, formal traits but must capture the spirit of the enterprise. Donning academic gowns and hats by itself does not contribute at all to the making of a university of excellence. Publishing voluminous national plans in slick covers, which utilize a full formalistic policy terminology, in itself also amounts to nothing. The same is true for a new building with a prominent nameplate and an elaborate administrative staff.

To be sure, acquiring these externalities is much easier than penetrating the essence of institutions and practices. The latter takes time, whether this acquisition of essence is by adoption and adaption, or by novel creation, or by a combination of the two. Yet this is what the emphasis must be on, and it can be argued that, in this respect, the acquisition of the externalities is not only useless but in fact counterproductive, since it gives a false feeling of accomplishment and hence fosters complacency.

The fourth consequence of the systemic nature of science building I want to stress is the importance of linkages. A system is characterized not only by having many parts, but, even more importantly, by having even more linkages among all those parts. The building of such linkages is especially neglected in the developing countries. Education, under the banner of functionality, is made very narrow and specialized, thus rendering the resulting manpower highly nonfunctional. The level of development is uneven, being mainly based by a few exceptional, energetic, and knowledgeable individuals who emerge here and there, and create some progress in their particular narrow areas of influence for a few years until the envy and hostility of their much more mediocre environment brings them down. All this is detrimental for the building of linkages among the elements of the science and technology system and among it and the other aspects of the country's development with which they are supposed to interact.

Finally, as a fifth consequence of the systemic nature of science building, I want to emphasize the importance and, at the same time, the difficulty of assessing the system at every stage of its evolution. The rudimentary and imperfect system itself prevents having in place an appropriate and functional assessment system which could give a realistic indication of how the development is proceeding. Perhaps small elements of the system are evaluated, but using methods which are so formalistic, narrow, and myopic that the progress of the system as a whole is lost sight of.

Research institutions turn in progress reports by the investigators or the directors which are then scanned by a personnel of bureaucracies with no personal experience in science-making. Thus the assessment consists of checking whether the progress reports say that they have accomplished what the original proposal for research support said they would accomplish.

There is a reluctance, due to a variety of causes, to resort to a peer review by the worldwide scientific community, and hence the body of experts that can be used for the evaluation is tiny, containing individuals who often have an axe to grind. Similarly, the decisions on how to distribute resources for scientific work is also hampered. I want to stress here that I am not talking about outright corruption, political, ideological, or social. Even in a totally non-corrupt environment, assessment becomes extremely hard because appropriate means of assessment presuppose a well developed indigenous science system which does not exist yet. Another illustration of the vicious nature of science development.

My aim in listing a few consequences of the systemic nature of science development is to set a background for a few general science policy pointers, to be discussed in the next section. These pointers, in accordance with the analysis of the present section, will be broad, and more attitudinal than specific. To be more specific would run the risk of seemingly giving recipes, and would also prevent the policy maker from the essential element of evolving his own way of proceeding.

Some Guidelines for Science Policy

Especially at the beginnings of the evolution of an indigenous scientific infrastructure, it is important to work from the bottom up. This promotes realism and avoids a top-heavy policy-making structure. Specific problems as annunciated by the local scientists and those local people who make use of the results of science need to be addressed.

Another way of making this point is to differentiate among planning, decision-making, and implementation. The balance among these three is likely to be grossly distorted in developing countries. Elaborate plans remain in limbo, are not followed by specific decision making, and no implementation is undertaken. This is made possible, in part, by the already mentioned lack of evaluation and assessment of the output of science. Plans are definitely input, whereas implementation comes much closer to output.

It is often believed that there can be no implementation without planning. This is in general untrue, or at least quite misleading. There is no need for a broad, general, and elaborate science plan to precede implementation of many useful measures to promote the growth of an indigenous scientific infrastructure. Some of the advanced countries who are leaders in science never had overall science plans.

Implementation can often be done in a very decentralized manner. This is essential especially in an environment where the infrastructure is just being built, and hence where overall coherence and coordination is not yet to be expected. In many developing countries where I have had the opportunity to witness considerable progress in one or another domain of science building, this progress came about by the decentralized action of a few outstanding individuals, who, within their own domain of influence, and by applying their own efforts independently of others, focused on modest, limited goals and achieved them. This mode of operation can be learned only by trial (and occasionally error). It cannot be taught (as a trick) at science policy workshops, or from manuals of science management.

Those involved in making and carrying out science policy need to have had some personal experience with doing science. Even better, they need to come from the active scientific community. This presents problems. Some of these exist everywhere around the world. Active scientists, when involved in science management, may get divorced from their scientific research field so much that rejoining it becomes impossible. The system of rotating such science policy personnel by employing active scientists for 2-3 years only and then replacing them with others on a rotation basis can work well.

Additional problems arise in this respect in the developing countries. The civil service bureaucracies are often so rigid that such rotation becomes very difficult to arrange. In addition, being a bureaucrat carries much more weight, influence, and prestige in developing countries than is likely to be the case elsewhere, thus representing a temptation to leave science forever. This is enhanced by the great positional security such civil service jobs hold out, compared to the constant struggle an active working scientist in a developing country is engaged in to create the circumstances under which pursuing science is possible. More than one of my former students who were promising scientists when they did their thesis work with me fell by the wayside scientifically a year or two after their return to their home countries when they were sucked up into the administrative machinery and were asked to carry out tasks for which they were severely overqualified.

Of all the various dimensions of science building, manpower and human resources in general are, in my view, the most important. A primary reason for this is that the development of a sizeable and appropriately qualified scientific manpower is a very slow process, and hence is likely to form the bottleneck at any given time. Therefore this, and not the lack of money, or the lack of buildings, or the lack of science plans, must receive the primary attention in science policy.

A very central and much neglected aspect of this focus on manpower is the proper realization of the main function of a scientist in the overall development of an infrastructure. An overwhelming fraction (more than 99%) of the science a developing country needs for its technological needs and for the support of its economy will be created outside that country, simply because the indigenous scientific infrastructure of the country is only a tiny fraction of the worldwide scientific community. Hence the primary need of the country is to be able to take advantage of this needed science which exists somewhere abroad.

This scientific knowledge is "free" in the sense that most of it is freely and openly available. It can, however, be pinpointed, understood, screened, adapted, and interpreted only by well prepared indigenous scientists. In this sense the knowledge is not "free", because in order to use it, a country has to invest into creating an appropriate indigenous scientific manpower that can access that knowledge.

In this sense, therefore, the personal research of the scientist becomes quite unimportant for the needs of the country compared to the value of this scientist to the country in terms of the scientists serving as a channel of scientific information from abroad into the country.

There are two important policy consequences of the above observation. First, the particular topic of a scientist's research should not be of great concern to the science policy makers, as long as this scientist is a good researcher, and through that is very much a part of the worldwide scientific system in a domain that is much larger than the specialized research topic of the scientist.

For example, somebody may work on some problems of electric conductivity of metals, but through that can be expected to be well conversant with general developments in solid state physics, so that he can serve as a funnel of these developments into the country.

The second policy consequence is that a focused and conscious effort needs to be made to utilize the scientists for this purpose of information transmittal. It would be an arrangement benefitting all parties if a scientist in a developing country, in return for a reasonable amount of research support and time to work on it four days a week, would be asked to spend the fifth day briefing his colleagues, technologists, leaders of the productive sector, government decision makers, and other interested people in the country about important developments in the sciences. I have yet to see, however, such an arrangement realized in practice. The perception in the developing countries of the value of a scientist is quite different: It is thought, I do not understand by what logic, that it is the results of the personal research work of the scientist that will be the main factor in promoting development in the country. Such a view runs counter to both of the policy concerns outlined above.

Epilogue

I want to end this brief discussion on a positive note, one that is not meant as a polite phrase but has grown out of my observation of science in the Third World for some 25 years.

During these 25 years I had the good fortune to observe much progress in many developing countries in the area of the evolution of the indigenous scientific infrastructure. I cannot say that such progress is evident in all countries, but the exceptions are few compared to the number of countries confirming this optimistic observation.

The most important cause of this progress appears to be that as the successive generation of scientists appear on the scene, they have an increasingly richer opportunity for a good scientific education, for practicing scientific research, for communicating with other scientists and technologists, for linking their work with other activities in the country. Seldom does one have the feeling that the progress arose from the formal science policy activities. The advances go much deeper, are more intimately connected with the efforts and thinking of individuals, and are related to the growing confidence and purposefulness of the indigenous scientific community. These elements are all internal to the country, and cannot be imposed from the outside, though perhaps it can be subtly encouraged and strengthened by recognition from abroad.

There is no reason to believe that the countries who started the scientific revolution late cannot eventually become as successful in it as others. What I have seen in the 25 years of observation confirms this. Appropriate "policy" for science, in most cases, can only speed up the process (and inappropriate policy can retard it). Thus science policy in development needs to be viewed in such a light, as a servant of the aim of releasing the country's latent potential to participate in the pursuit of science, one of the most prominent and successful human activities of the 20th century.

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THE CARIBBEAN: CAN LILLIPUT MAKE IT?

Wallace C. Koehler, Jr. and Aaron Segal

The mobilizing of science and technology for development in the Caribbean is proving to be agonizingly slow. Efforts to foster indigenous capabilities are at very different states from country to country but their impacts are still limited.

We define the region as consisting of the islands of the Caribbean Archipelago and the culturally related countries of Belize, Guyana, Surinam and French Guiana with the majority of their populations living on the Caribbean Sea. This provides in 1987 a region consisting of over 30 million people in 22 independent and non-independent countries speaking English, French, Spanish, and a variety of dialects and Creole languages. It is in this region that scientific and technological exchanges have existed for several decades and where a rudimentary regional S&T network is beginning to take shape.

Our emphasis is on the development of indigenous capabilities for research, development, demonstration, adaptation and diffusion of science and technology (R,D,D,A, and D). Our interest is in the human resource capabilities of the Caribbean peoples.

Tradeoffs and contradictions between equity and efficiency goals, ecological and economic growth objectives, are persistent in the region.(1) Currently indigenous S&T is so limited that it makes a minimal contribution to any of these objectives, not even in Cuba which invests more in research than anyone else in the region. The evolution of indigenous capabilities can be measured in several ways including publications and citations in internationally circulating journals, patents and copyrights, R&D expenditures, cost-benefit analysis of research projects, quality of life indices, and air and sea pollution counts. The scanty evidence indicates that the Caribbean has little formal or informal shop-floor R&D.

History of Caribbean Science and Technology

There was a long uneven history of science and technology in the Caribbean which remains to be documented. Science for several centuries was the prerogative of learned amateurs; botanists, naturalists, physicians and others. Technology was mostly imported and lightly adapted. Rarely was either institutionalized.

The first significant Caribbean adaptations of science and technology occurred in the late 19th and early 20th century century with the introductions of the steam engine, railway, and control of yellow fever and other mosquito-borne diseases. The striking decreases in mortality in Cuba, Puerto Rico and the West Indies after 1900 were the result of applied research, demonstration and diffusion.(2) These successes contributed to the establishment in the 1920's of modest agricultural, tropical medicine and public health research facilities.

A longer version of this work has been published in Aaron Segal, Learning by Doing: Science and Technology in the Developing World, Westview Press, 1987, pp. 55-81.

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In general the Caribbean colonial heritage in science and technology was meagre, largely oriented towards production of export crops, and failed to provide career opportunities for local scientists. Secondary and university education retained a humanities and law bias and predominant enrollment throughout the colonial period. Rigid race and class stratified societies failed to diffuse popular knowledge of science and technology.

The drive towards indigenous science and technology capabilities has roots in Caribbean political nationalism. It is an expression of the desire to reduce political and economic dependency, to provide outlets for national creativity, and to generate economic growth which is subject to national direction. The two themes of indigenous R&D for new exports and for appropriate technologies were linked to the desire to alter the terms of technology transfer.

The concern for national science and technology policies, planning and institutions began in Cuba in the 1960s and by the 1980s reached most of the region. The concept that science and technology required government force-feeding as well as regulation was promoted by several United Nations agencies, especially the Economic Commission for Latin America. This concept was fortified by the energy crisis of the 1970s and the felt need of governments to respond with coherent national energy policies. Conferences, seminars and workshops spread the message to politicians, civil servants and researchers. All independent Caribbean governments were asked to present national science and technology plans at the 1979 UN Conference on Science, Technology and Development. Most complied and for many it was their first attempt at a policy statement.

The new government awareness of possible roles for science and technology has not been accompanied by private sector or academic participation or much public support. Scientific communities within the Caribbean have vastly extended their formal and informal contacts over two decades but their principal ties are still outside the region. Lacking internal funding, adequate equipment, competitive salaries, technicians, and information services, most Caribbean national scientific communities are loosely structured and organized. At the regional level their ties are still embryonic. The pressure for mobilizing science and technology has come from the politicians rather than the scientists.

The promise of a mobilized science and technology can only be realized if and when indigenous infrastructures come into being. This requires years of effort at improving and extending the teaching of science in the schools, popular science and technology education programs for adults, the establishment of critical masses of well-funded and supported researchers effectively networked within and outside the region, and agreement on research priorities. There are few shortcuts without an infrastructure and no shortcuts to its achievement although its size will vary. A quick review of national efforts to date conveys the state of existing infrastructures and research program.

National Efforts

Cuba is the only Caribbean state to have made research and development on sugar its primary concern. Three decades of expensive and intense efforts with Soviet help has produced mixed results. Although Cuba is the leading sugar producer in the world it does not export sugar technologies on a significant scale. The Cuban-Soviet designed mechanized sugar harvester built in Cuba since 1977 is inferior in productivity and more expensive to operate than Western commerical harvesters.(3) Cuba has mechanized about fifty percent of its cane harvests through combinations of imported combines, its Cuban-Soviet made combine, and the extensive pre-burning of cane.

Cuba has the most impressive science and technology infrastructure in the Caribbean but it is not working well.(4) At the top is the Cuban Academy of Science which administers a dozen major institutes, science documentation centers, and S&T planning. Universities are relegated to training and some applied research while enterprises lack funds and authority to engage in shop-floor adaptation and innovation and learning by doing. The central research institutes are poorly linked to universities and to enterprises. Investment in R&D, especially sugar mechanization, does not appear to be fostering economic growth or reducing external dependency. The major Cuban equity gains in extending education, health, and other services have been achieved through management and investment, not R&D.

Puerto Rico has a science and technology infrastructure in search of a policy. Next to Cuba it has the largest number of researchers and research spending in the region. US federal government agencies support agriculture, forestry, fisheries, climatology, and other basic and applied research in Puerto Rico. The University of Puerto Rico and several other newer Puerto Rican universities carry out applied and basic research. The Puerto Rican government has modest applied research programs in a number of fields. While the private sector relies basically on unrestricted technology transfer from the United States, there is evidence that some informal shop-floor adaptation goes on in Puerto Rico.(5)

The Dominican Republic has fragmented and highly uneven research in agriculture, alternative energy systems, fisheries and other areas.(6) Government ministries, parastatal corporations, non-profit foundations, and the universities compete for far too few researchers, technicians, and funds. Efforts at coordination through science and technology offices in the Presidency and presidential science advisors have faltered. Each R&D unit seeks to jealously guard its turf. The National Energy Policy Commission was established in 1979 and has launched several research programs but with little coordination or coherence.

Haiti has for its 5 million population the weakest science infrastructure in the region. Three decades of brain-drain have resulted in more Haitian researchers abroad than within the country. A handful of foreign-funded projects in agriculture, alternative energy, and reforestation through fast-growing species go on but without an infrastructure. High turnover, low salaries, poor networking, no information systems, and other problems quickly frustrate researchers. National plans and policies are reduced to empty words in the absence of an infrastructure or serious efforts to create one.

One of the few hopeful elements in the Haitian picture is the remarkable informal learning by doing of Haitian entrepreneurs in producing local components for assembly plants. Joseph Grunwald of the Brookings Institution recently conducted a study comparing backwards linkages in assembly plants in several countries. He found that Haiti's record was outstanding, taking advantage of low-cost labor, and tax and other incentives to replace imported with local components for baseballs and other products.(7)

The French Antilles and Guiana and the Netherlands Antilles still rely on metropolitan countries for most of their science, technology and institutions. This results in excellent marine biology, tropical forestry and other centers manned by European scientists. Applied research on local problems has had though to wait the organization recently of local universities and research institutes.

The Caribbean independent mainland states of Belize, Surinam and Guyana share low population densities, large tracts of undeveloped territory, and the possibilities of unexploited natural resource. Their research efforts and policies are at similar stages of seeking the funds, personnel and organization to carry out comprehensive natural resource surveys.

The smaller Leeward and Windward Islands lack policy, planning, institutions, researchers, and research. Scattered projects are externally funded and implemented, often on alternative energy, with minimal local participation.

There is an enormous contrast between the R&D capabilities of Trinidad and Tobago and those of the rest of the Eastern Caribbean. Housing a University of the West Indies

(UWI) campus, the Caribbean Industrial Research Center serving the private sector, a branch of the Caribbean Agricultural Research Development Institute, and various government ministry efforts, Trinidad has a working if inadequate infrastructure. The government decision to invest oil revenues in joint venture industrial export projects in petrochemicals has also improved local information and documentation capabilities. Trinidad has and should continue to provide advice on technology and technology transfer to the Eastern Caribbean.

Like Puerto Rico, Trinidad has an infrastructure in search of a policy. This is reflected in the discussions over a strategy of joint ventures and technology transfers, industrial import substitution, and the proposed National Institute of Higher Education, Research, Science and Technology. Small-scale scattered applied research efforts in a number of areas including agriculture and marine biology have limited impacts.

Barbados has relied on informal and formal networks to achieve coherent if modest performance. It benefits from the location in the country of the Caribbean Development Bank (CDB), the headquarters of the Caribbean Meteorological Institute (CMI) and other regional organizations with technical capabilities, including the local campus of the University of West Indies. It has achieved some success with commercial dissemination of work on biogas digesters, solar heaters, and agro-industry. It has also recently surveyed its research, researchers, and spending and has baseline data generally absent elsewhere. The role played by universal literacy, public awareness of S&T, and informal public-private sector linkages has given Barbados an edge.

Jamaica has had a topsy-turvy experience with science and technology in recent years including a stark exodus of professionals and technicians in the 1970s, and a drastic switch from emphasis on controlling the transfer of technology to encouraging uncontrolled transfers. There have also been numerous changes in personnel in institutions responsible for science and technology. What has continued is a basic and applied research capability at the Jamaica campus of UWI; especially at the Medical School and the Caribbean Food and Nutrition Research Institute; a tradition of government research in agriculture as well as private efforts, and some scattered energy, fisheries, and other R&D. A key problem is too many small, uncoordinated research efforts underfunded and understaffed.

These thumbnail sketches of national efforts are partial, subject to change, and arbitrary. They do indicate the enormous range of science and technology experiences and approaches within the region, and the basic obstacles to regional cooperation. Such cooperation at present consists of the Caribbean Community (CARICOM) nations whose relations focus on politics and trade but also includes, UWI, CMI, CDB, the Caribbean Examination Council, and a number of non-governmental professional associations. At the regional level the Association of Caribbean Universities and Research Centers (UNICA) founded in 1967 has continued a low-profile program of conferences, workshops and exchanges of information and has discussed possible joint research projects. Its membership includes universities throughout the Caribbean, as well as Colombia, Venezuela, Mexico, and the US, but Cuba has not joined.

The Commonwealth Caribbean has attempted several regional science and technology projects and proposed others. Using US funding, the Caribbean Development Bank and the CARICOM Secretariat have spent $7 million over five years on small-island alternative energy research. The CDB also operates a Technological Consultancy Service for the Eastern Caribbean. The Organization of American States has had several small-scale subregional projects.

Instead the focus since 1979 has been at the Caribbean-wide level with the initiative coming from ECLA and UNESCO and a few individuals such as Dr. Dennis Irvine, former Vice-Chancellor of the University of Guyana. These efforts produced in 1981 the intergovernmental Caribbean Council of Science and Technology (CCST). Its membership includes most of the CARICOM states plus Cuba, the Dominican Republic, Haiti, and even the Netherlands Antilles as a possible non-independent Associate Member. It is the widest Caribbean governmental grouping for science ever except for the World War II and postwar Caribbean Commission that was confined to the colonial powers. However, several CCST members have not paid their dues, lack of internal and external funding has continued reliance on ECLA for Secretariat services, and member participation and interest is markedly uneven.

The state of regional and sub-regional activity is growing but still incipient. The dilemma is that without much more extensive regional cooperation many Caribbean countries will be shut out of science and technology.

The present state and prospects for S&T in the region need to also be examined by sectors. Our discussion attempts to highlight the issues in each key research sector.

Alternative Energy Research

The Caribbean is 90 percent dependent on imported oil at present to fuel its energy needs (Trinidad and Tobago is the only oil and gas exporter, Barbados and St. Vincent produce some oil and gas). Yet the Caribbean and other subtropical islands have energy advantages not necessarily shared by other developing countries. The energy opportunities associated with coastal activities are of particular interest.(8)

It is generally recognized that the Caribbean possesses a wide array of energy resources which may be exploited to provide from a small to a large proportion of indigenous energy needs. Renewable energy presents the greatest opportunities. There is extensive solar insolation, the winds tend to be strong and predictable, good ocean thermal potentials exist, several countries have geothermal and/or hydro resources, and the biomass resource base is large and varied. In spite of lower world oil prices the extreme dependence of the Caribbean on imported energy remains a severe economic burden, and research on alternative energy an important opportunity.

The track record of energy research in the region is mixed to date. There is a lengthy list of donors, projects, and sectors which includes foreign governments, international organizations, private foundations, and others. Some governments have responded by organizing their own national policy offices as in the Dominican Republic, Puerto Rico and elsewhere.

The goal of reducing energy dependency has been widely accepted but not translated into action. Recognition that energy research requires long-term commitments to infrastructure in order to train, retain, and retrain qualified researchers has often been missing. Discussions of international, regional and national planning, policy, and cooperation skip the specifics needed to sustain energy research. Project by project episodic funding makes it difficult to develop those very indigenous research capabilities that are needed.

Agriculture and Forestry

Export crops such as sugar and sea-island cotton have provided the historically most effective examples of Caribbean public and private sector research linkages. Discouraging markets and prices for traditional exports present new challenges to a post-colonial research structure.

There are advocates of new research programs on non-traditional export crops such as fruit trees for whose products new markets may exist.(9) The emphasis is placed on commercialization and marketing. Others maintain that research should focus on low-cost,

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labor-intensive technologies at the disposition of small farmers with little credit or formal education. Then there are those who argue for agro-industry research to adapt known dairy, poultry, sheep and pig, animal fodder and other conditions to Caribbean commercial agriculture and food processing. The emphasis here is on agricultural extension, mechanization, and technology transfer with the goal of reducing present extremely high food imports.

The debate over research approaches and goals divides governments, ministries of agriculture, researchers, university faculties of agriculture, external donors and others. It even occurs in Cuba where the small remaining private sector is denied research but still out yields the state farms.(10) It is a debate with a different balance in each country due to the different prevailing systems of land tenure, extent of rural migration, and other factors. For instance Puerto Rico has opted for agro-industry research in a society where few small holders remain; Haiti is overwhelmingly rural and small farmer and concentrates on labor-intensive research. The debate is further complicated by the possible use of sugar for fuel and its economics.

The problem is that at the national level the resources are lacking to effectively pursue several agricultural research strategies at the same time. Work on new crops and traditional crops such as sugar and bananas must be carried out at the subregional or regional level for the smaller countries.

Appropriate Technology

The concept of labor-intensive, small-scale technologies have received an enthusiastic reception in much of the Caribbean. Church groups, non-profit foreign donors, and other organizations have sponsored centers, fairs, meetings and demonstrations. Results are uneven and mixed but an important increment to adult technology awareness and skills has occurred, especially in the small islands. The appropriate technology groups have also developed formal and informal networks and information-sharing; an important lesson for the scientific community. While its total economic contribution may be limited, appropriate technology efforts in the region are a welcome sign of self-reliance. Where local interest merits appropriate technology efforts may be extended to crafts, construction technologies, materials recycling, and small industries.

Environmental Sciences

The Caribbean consists of densely populated highly fragile human and organic ecosystems subject to periodic hurricanes, earthquakes and manmade disasters such as oil spills. The environmental sciences are recent arrivals in the region although there is a distinguished record of academic research in marine biology in Puerto Rico, Trinidad, Jamaica, Barbados, Curacao, and elsewhere. Recognition of environmental concepts has been stressed by UNEP, UNESCO with its Man and the Biosphere research program, and by the non-governmental Caribbean Conservation Association.

The growth versus pollution debate of the 1960s and 1970s has a different context in the Caribbean. Pollution in a closed island ecosystem threatens survival in a way that it does not in Calcutta or Mexico City. There has been growing demand for applied research on short-term problems of harbor pollution, oil spills, coastal zone management and beach and sand erosion and coastal and fish farming. There are political demands for research to improve fishing practices and yields, reduce imports and generate employment.

Unfortunately increased interest in ecological research has not been matched by a strengthening and revision of environmental science infrastructures. Technicians are desperately scarce making fisheries and marine extension programs unrealistic. Research centers lack critical masses of researchers, and adequate information services with a consequent loss of staff. Important work has been done in Caribbean archaeology, marine biology and other fields but often through collaboration between local and better-equipped foreign researchers.

Climatology and seismology are the two disciplines in which Caribbean applied research and international basic research interests have been bridged. The Caribbean Meteorological Institute collects weather data for the Eastern Caribbean and uses satellite data for forecasting and hurricane and storm warnings. Its cooperation and that of other Caribbean national weather services with US agencies has markedly improved regional forecasting capabilities while adding to global data. Similarly international oceanographic and seismic work on the Caribbean has added to basic research knowledge of tectonic plates and planetary climatic history.(11) The lesson is that the Caribbean can participate in first-rate basic research by providing facilities and staff and matching applied to basic research interests. The principal advantage comes from on-the-job training of Caribbean researchers.

Industrial Research

There is very little formal industrial R&D in the Caribbean and an unknown but presumably limited amount of informal shop-floor adaptation. Cuba is the sole exception with its need to adapt Soviet and East European capital goods and its efforts at industrial import-substitution including designing its own micro-computers. Elsewhere technology transfer is largely unregulated except for foreign exchange constraints. Industrial technology institutes in the Dominican Republic, Trinidad, and Jamaica provide information services, consulting, and some trouble-shooting for the private and public sectors.

Information and Social Sciences

There has been more than 50 years of solid scholarship in the social sciences in the Caribbean, much of it by local scholars. Topics such as race and class, kinship and gender, Africanisms in the New World, the plantation economy, emigration and others have been competently studied over several decades. The research findings have been widely diffused and constitute part of the basic world views of many Caribbean people. There are a number of social science research centers in the region, notably the Institute of Social and Economic Research of UWI, and a steady stream of publications.

While research must continue on the topics first delineated before World War II there are signs of new emphases. Management of enterprises -- public, private, non-profit, cooperative, etc. -- urgently requires understanding in these societies. Urban planning, land use, coastal resource management, are intellectual imperatives for research in the face of rapid change. Researchers need to come to grips with tourism as a multidisciplinary phenomena requiring highly sophisticated research rather than superficial analysis. Longitudinal and cross-cultural research which treats the entire region as an entity has yet to be realized. As science and engineering research in the region increases the social sciences which have played a leading role need to expand their interests and empirical data bases.

Health Sciences

The Caribbean strength lies in applied research such as drug trials, demonstration and diffusion. Basic research on tropical medicine continues in Cuba, Jamaica and Puerto Rico but major advances are likely to be made elsewhere. Instead the challenge is to devise and implement para-medical health delivery systems in those countries where universal hospital and physician based medicine is not feasible.

Human Resources

The Caribbean for two decades has barely been able to replace its existing numbers of researchers and in several countries such as Haiti there are fewer researchers now than there were in 1960. Investment in science education and science teaching at all levels is the highest priority due to the long lead-times needed to train researchers. Augmentation of science education with fairs, clubs, prizes, science museums, audiovisual materials, etc. is vital and lends itself to regional cooperation. Science education for adults is also important on the job, through clubs, unions, and other organizations. The goal should be augmented job-related knowledge and skills rather than a vague awareness of the importance of science. Audiovisual and computer on the job training should be attempted.

Numerous studies have shown that researchers emigrate due to frustration with local working conditions and salaries as well as foreign opportunities.(12) The Caribbean has the advantage of geographic proximity to major research centers and possible on-line communications. Keeping good researchers in the region requires providing them with frequent keep-up access to major centers, on-line data bases and overseas communications, and centers with "critical masses" sufficient to permit stimulating exchanges. Handfuls of isolated researchers scattered around the region are not productive. Adequate information systems and telecommunications are a sine qua non of effective Caribbean R&D; not luxuries. The alternative is to continue to see some of the best people emigrate.

Research Priorities

We argue for highest priority to in situ research on problems unique to the region where transferable technologies will not work or must be adapted. Renewable energy systems and agriculture and appropriate technology fit this criterion. So does research on Caribbean ecosystems. Investments in information science, improved telecommunications and science education are needed to make any R&D program possible, including our suggestions. The priorities we propose require infrastructure buildups and cannot promise economic results before the 1990s. We do not believe that there are short-cuts in the Caribbean. Science and technology in the region must be nourished before it can deliver.

Approaches

Currently a majority of Caribbean R&D is directly externally funded in every country except Cuba. Indigenous capabilities need to be increasingly funded from indigenous resources.

Most R&D in the Caribbean will continue to be carried out at the national level, whatever the sources of funding. Funding needs to be restructured to facilitate user-researcher linkages. Fiscal incentives can be tried to induce the tourist sector to fund solar energy; agro-industry to support university work, etc. The self-imposed segregation of researchers and possible users must be forcefully broken-down or no diffusion will occur. Where national councils of science and technology exist there should be broad participation of trade unionists, farmers groups, teachers, etc. The smallness of these societies should be an asset for research diffusion and not a liability. Public sector corporations like the electric utilities should have set aside R&D funds to be used for contracting with universities and the private sector. Linkages should explicitly aim at strengthening local and regional engineering and design capabilities. Non-profit organizations also have an important role to play in R&D support. The donors can create supply but demand for research is a function of linkages established nationally.

Conclusion

How to get from nowhere to somewhere? The Caribbean at present does not have sufficient science and technology capabilities to effect its own future. Compare this to India which was able to demonstrate, adapt, and diffuse the Green Revolution to change from a net food importer to being self-sufficient. Compare this to Singapore which has developed the ability to increasingly design and produce its own industrial exports. It is possible for the Caribbean within a decade to have the indigenous capability to alter its future in energy, agriculture, and ecology.

The alternative is also visible. It is a perpetuation of the status quo. Most energy is imported depending on the vagaries of world markets, prices, and politics. More and more food imported and more and more rural people leave for Kingston, Port-au-Prince, Miami or New York. Ecological pressures increase, more beaches erode, forests denude, and finite natural resources dwindle. The alternative is not apocalyptic but it is not pleasant. Science and technology do not have the answers to the outstanding problems of the Caribbean but they tell us how to look.

Notes

1. Fuat Andic, "Efficiency vs. Equity, Economic Policy Options in the Caribbean", Caribbean Review, Vol. XIII, No. 1, Winter 1984, pp. 16-20; Carl Stone, Power in the Caribbean, (Philadelphia: Institute for the Study of Human Issues, 1985) discusses Caribbean political systems in relation to growth and equity objectives.

2. J. Diaz-Briquets, The Health Revolution in Cuba (Austin: University of Texas, 1983), pp. 35-53. Similar rapid reductions in mortality followed the introduction of public health measures in Puerto Rico, and the British West Indies. The development of Caribbean sugar cane-breeding capabilities based on imported varieties is another early 20th century example of quick technology transfer.

3. Charles Edquist, Capitalism, Socialism, and Technology, A Comparative Study of Cuba and Jamaica, (London: Zed Books, 1985). Comprehensive studies of Cuban science and technology are not available. Limited or partial accounts include Tirso W. Saenz y Emilio Garcia Capote, "Ernesto Che Guevara y el Progreso Cientifico Tecnico en Cuba," Interciencia, Vol. 8, No. l, Jan.-Feb. 1983, pp. 10-18; Marcel Roche, "Cuba: El Centro de Investigaciones Biologicas," Interciencia, Nov.-Dec. 1985, Vol. 10, No. 6, pp. 299-300; and Angela Tomeu Miranda, Cristobal Ellipe Gonzalez y Soledad Diaz Otero, "Ciencia, technologia y empleo en el medio rural cubano," in Viviane B. Marquez ed., ciencia, tecnologia y empleo en el desarrollo rural de america latina (Mexico: El Colegio de Mexico, 1938), pp. 261-286.

4. The problems of low productivity in the Cuban economy are frequently cited by Fidel Castro and other leaders. They are discussed in Carmelo Mesa-Lago, The Economy of Socialist Cuba (Albuquerque: University of New Mexico, 1981), pp. 179-182.

5. The Center for Energy and Environmental Research of the University of Puerto Rico conducted in 1984 a survey of industrial R&D in Puerto Rico. The results indicate very little formal R&D, mostly by Puerto Rico based companies, with somewhat more adaptation and dissemination.

6. Sources for impressions of the Dominican Republic and other Caribbean countries except Cuba include personal visits by the authors, interviews, the Internews section of Interciencia, the 1981 and 1982 reports to UNESCO on "Science and Technology for Development in the Caribbean: Current Status and Possibilities for Regional Cooperation" by Dr. D.H. Irvine. Latin American Newsletters, Science and Technology in Latin

America (London: Longman, 1983) has brief sections on Belize, Cuba, the Dominican Republic, French Guiana, Haiti, Jamaica, Puerto Rico, and Surinam.

7. Joseph Grunwald and Kenneth Flamm, The Global Factory (Washington: Brookings, 1985), pp. 187-204 on Haiti.

8. Juan A. Bonnet, Jr. and Wallace C. Koehler, Jr., "Status of Energy Programs in Caribbean Islands," Proceedings, Energy Conference, Regina, Saskatchewan, Canada, May 1984.

9. Board on Science and Technology for International Development, Needs in Science and Technology for Development in Caribbean Island Nations, Report of a Workshop, August 30-31, 1982. (Washington: National Academy Press), pp. 32-41.

10. Carmelo Mesa-Lago, The Economy of Socialist Cuba (Albuquerque: University of New Mexico, 1981), pp. 138-139.

11. Jorge Enrique Corredor "Identificacion y Analisis de Ecosistemas del Caribe," Interciencia, Vol. 9, No. 3, June 1984, pp. 145-152.

12. Ransford W. Palmer, Problems of Development in Small Beautiful Countries (Lanham, Maryland: North-South Press, 1984), pp. 30-38 on Jamaican emigration. The extensive literature on Caribbean emigration since World War II includes only a few studies which focus on the "brain-drain" or highly skilled emigrants. See Rosemary Brana-Shute, ed., A Bibliography of Caribbean Migration (Gainesville: University of Florida, 1983).

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TECHNOLOGY WITHOUT LITERACY: AGRARIAN INNOVATION IN RURAL HAITI

Gerald F. Murray

Introduction

This paper, dealing with the diffusion of technologically innovative tree planting strategies among the nonliterate population of rural Haiti, may seem to differ in its focus from the other papers in this volume, concerned as they are with the role of technological literacy. But the disparity is only apparent; there is a unifying underlying issue: technological diffusion. Many of those writing about technological literacy are concerned with overcoming local barriers to the diffusion of innovative, appropriate technologies. To that agenda the lessons learned in rural Haiti -- lessons about trees learned by Haitian peasants, and lessons about technological diffusion learned by program planners -- are fully germane.

For my point will be that it is not the literacy or illiteracy of a population that need be the principal determinant of the rapidity of technological diffusion, but rather the manner in which outreach agents are able to reconceptualize, modify, and present the targeted technology to make it mesh with the preexisting economic, social, and personal agendas of the human beings in that population. Where this mesh is achieved programmatically, diffusion will occur despite illiteracy. In contrast, where this pragmatic mesh between technology and local life is not achieved, even a literate population presented with well written materials will probably reject the technology.

I will argue even more explicitly that this mesh can be achieved through the application to program design of insights gleaned from anthropological fieldwork. In many cases indifference toward or rejection of the technology by a population is due less to technological issues per-se than to accessibility, benefit-flow, institutional, or motivational factors whose identification is facilitated by anthropological rather than purely technological research. These abstract propositions about the potential untility of anthropology will be illustrated by a specific case study in which anthropological input in fact led to accelerated diffusion of tree planting among Haitian farmers.

The removal of Haiti's tree cover is now virtually complete. Both agrarian needs for land and the income-generating potential of charcoal have motivated peasants to cut trees. Peasants are aware of the deleterious long range ecological impacts of this behavior. But the **ecological** value of forest cover for soil conservation and moisture retention purposes is less urgent in the calcuations of impoverished cultivators than the current **economic** value of the tree in the local charcoal and lumber markets.

Caribbean governments have long recognized the problem and a standard response has been to stress the need for education, to urge the instilling of a "conservation ethic" among villagers. When educated as to the ecological utility of trees, villagers will presumably leave nature's trees alone, and will even plant new forests, with external funding and with local government support and supervision. In the context of such a model, silvicultural and educational experts will be brought in, slide shows and radio messages will be prepared, nurseries will be planted, and campaigns will be enthusiastically launched.

Rather than a burst of tree planting by ecologically awakened villagers, a more common result of such undertakings has been the death of tens of thousands of unwanted seedlings in nurseries that have been foolishly launched in the complete absence of any real local demand for the trees. Faced with such villager recalcitrance, agents begin reminding villagers of the government's right to command obedience in such matters of high national interest, and the secret war begins. Cultivators need land for food and cash crops. In addition governmental agents frequently insist that the trees, once planted, continue to belong to the government. Reluctant to cover their land with government-owned vegetation, villagers do everything possible either to avoid planting the seedlings or to have their livestock "accidentally" remove them once planted. It is clear that the barriers to tree diffusion had little to do with the illiteracy of the intended "beneficiaries."

Redefining the Problem in Anthropological Terms.

The Agroforestry Outreach Project (AOP) was designed as an anthropological alternative to this governmental approach. It began in 1982 and has continued to function effectively despite the political turmoil in contemporary Haiti. My own input came at several phases. Before being invited by USAID to deal with the tree issue, I had already done several years of village fieldwork into Haitian peasant land tenure and agrarian technology (Murray 1977; 1978a; 1978b). Though this basic research had been done without a specific intent to apply findings to program design, USAID planners found the findings of potential relevance for their own programs.

This led to an invitation by USAID to do an evaluation of some 20 conservation projects. Two other anthropologists were also invited to conduct program-relevant research into tree planting (Conway, 1979; Smucker, 1981). The results indicated that most tree planting efforts targeted to rural Haiti had been rejected by the rural population. On the basis of my research, I hypothesized that the rejection had been due neither to technical nor "cultural" factors at the **local** level but to faulty problem definition and program planning at the **institutional** level.

Problem definition issues entailed a basic paradigm shift at the theoretical level. I proposed to planners that the theme of "conservation", though popular in developmental circles, was an unrealistic approach to the tree issue in the Caribbean. Even beginning anthropology students were aware that in ancient times *Homo sapiens* still depended on hunted protein and wild vegetation. We ran into a resource depletion crisis some 10,000 years ago: we engaged in overkill of the animals and overharvesting of the wild vegetation. One can imagine that even back then there were voices crying for conservation. But our solution as a species was not that of **conserving.** What we did rather was to **move into a domesticated mode of food production.** The wild animals were converted into domesticated herds; and people began planting crops rather than foraging wild vegetation.

Applying this "domestication model" to the Caribbean tree situation, I hypothesized that a redefinition of the "tree problem" was absolutely necessary. The task is not to coax an "irrational" population into protecting their environment by the cessation of tree cutting, but rather to create the conditions whereby rural cultivators will begin harvesting as a crop the wood which up until now they have been foraging from nature. The emphasis of the conservation paradigm is toward the **stoppage** of tree cutting behavior. The emphasis of a domestication paradigm, in contrast, is to promote tree planting with a specific view to **increasing** the cutting of trees and the returns derived therefrom. Stated somewhat differently, the tree should be presented to peasants not as an ecological "patrimony" to be perennially protected, but rather as a new **income generating cash crop** that farmers could plant and harvest (Murray 1979). That is, a basic paradigm shift seemed to be called for in the manner in which planners were conceptualizing the "tree problem."

Tripartite Planning Model: From Theory to Program Design.

When these abstract suggestions were accepted in principal, I was then invited to propose a concrete model of project design and outreach. Much USAID program planning focused on technical variables, the assumption being that an ecologically sound tree planting model would diffuse by itself. I argued instead for a tripartite planning model which gave simultaneous attention to **three** essential project subsystems: a technical subsystem, a benefit-flow subsystem, and an institutional outreach subsystem. Planning had to concern itself with all three. Defects in one would sabotage an entire project.

Designing the technological sybsystem.

Anthropological insights into local life can be used not only to adapt technological messages directed outward toward the client population. Of even greater preliminary importance are the insights that lead to modifications of the technological packages themselves. The tree planting technology required under a domestication model is quite different from that which would be appropriate under a traditional conservation model.

Some program planners try to emphasize fruit trees when dealing with smallholding cultivators with limited landholdings. Because, however, the income generating potential of fruit is much less than that of wood, AOP emphasized the latter. Furthermore the policy of emphasizing the slow growing precious hardwoods so popular with many tree lovers makes less sense in the rural Caribbean than a policy focused on **fast-growing** trees. Smallholding cultivators necessarily demand quicker returns and cannot afford to wait 40 or even 15 years for slow-growing trees. AOP therefore emphasized fast growing tropical hardwood trees which could produce harvestable trees in four or five years and whose wood could be sold locally for charcoal or lumber. The species emphasized in the earlier phases of the project were **Leucaena leucocephala, Cassia siamea, Azadirachta indica, Casuarina equisetifolia,** and **Eucalyptus camaldulensis.** For higher altitude regions, **Pinus occidentalis** was used.

And finally, as a critical dimension of the technological subsystem was the use of intercropping of trees with food crops to permit land scarce farmers to plant trees in a manner which minimized interference with their food growing activities. Intercropping and border planting strategies were proposed therefore for physically combining tres and crops. Such a strategy differs radically from a traditional reforestation model and falls into the category of what is referred to as **agroforestry.** Summing up the preceding, the main contribution of anthropology was in the identification of the modifications necessary in the technology itself to make it mesh with the preexisting economic system of the population that was presumably to use the technology.

Designing the benefit-flow subsystem.

Well designed technological packages will sit unused in laboratories or nurseries unless simultaneous planning energy is allocated to the designing of benefit-flow systems. By this I am referring to the embedding of the technological package in ownership and usufruct structures that leave no ambiguity as to the identity of the eventual beneficiaries. The traditional rejection by rural Caribbean populations of tree planting projects is due neither to their hostility to the tree nor to their ignorance of the "value of trees." They know perfectly well that trees protect and restore the soil and that wood is an extremely valuable commodity. Their rejection stems rather from their well founded fears that the **real** benefits -- i.e. not the far off ecological improvements, but the money to be made from the harvesting of the wood -- will accrue to other social groups. Most reforestation projects make the government the owner of the trees or leave ownership of the planted trees ambiguous. Many projects which make participating farmers the owners of the trees will follow up with the chilling warning, however, that they are not allowed to cut "their" trees, a most strange form of ownership indeed. In short, no matter how ecologically and technically sound the selection of tree species, no rational farmer will cover any of his land with vegetation for whose harvest he could end up in jail.

In view of these considerations I recommended the following measures to activate a benefit-flow system by which there would be an unambiguous flow of benefits directly to the participating farmers. I first urged that the project allocate several hundred seedlings free of charge to each farmer who wished to participate. In contrast to most other Haitian tree planting projects, however, there would be absolutely no wages paid for the planting of trees. Furthermore the farmers would be the sole owners of the trees which they planted on their land. And above all they would be able to harvest and sell the wood from their trees without asking project permission.

Stating this somewhat differently, the project addressed the benefit-flow issue by embedding the tree in the same type of private ownership and usufruct structure that governs the planting and marketing of other crops in the farmers' agrarian inventory. We vigorously rejected the misguided attempts of many other projects to make the trees government property or community property. Farmers will not use a new technology unless they are convinced, first, that the new technology will yield higher returns and, secondly, that they, not somebody else, will be the beneficiary of these increased returns. This is, of course, merely common sense which requires no Ph.D. in developmental planning. That these common sense principles were viewed by some as revolutionary breakthroughs in developmental planning merely symbolizes the irrational character of much of what goes on behind closed office doors.

Designing an institutional outreach strategy

Even when the first two design problems -- technology and benefit-flow -- have been adequately addressed, a technology transfer project has one more dangerous chasm to cross. A well designed technology embedded in positive benefit-flow channels will still be to no avail if the funds and implementing authority of the project are entrusted to incompetent or predatory institutions. The traditional practice of turning over tree planting funds to Duvalier's government for implementation would have guaranteed beforehand the failure of the project. Though the predatory skills and mismanagement achievements of the Duvalierist regime had achieved world renown, managerial mediocrity seems to be characteristic of governmentally mediated projects around the world.

To deal with this issue I recommended a non-governmental implementation mode. Though space restrictions prevent details here, interested readers may consult Murray 1986. A two-tiered non-governmental resource-channeling structure was created, consisting of a centrally funded office in the capital city which entered into contractual relationships with Private Voluntary Organizations (PVO) throughout Haiti. These local grassroots organizations were the direct link with potential village tree planters. The conditions of participation in the project were explained and the PVOs drew up lists of interested farmers. The seedlings were produced and delivered regionally by the Project. Individual participants were responsible for the final transportation to the hillsides.

Project Results

The initial project goal had been to plant three million trees on the land of some six thousand Haitian villagers over the four year life of the project. Given the traditional antipathy of the Haitian peasants, if not toward trees, at least toward tree planting projects, this goal seemed quite high. But it was forced on the project by an economist examining projected internal rates of return to project funds. However the anthropological design principles that had been incorporated into the project touched an economic nerve in rural Haiti. When learning that they, not the government, would have ownership rights over the trees, tens of thousands of peasant cultivators all over Haiti lined up for the trees. By the end of the fourth year, the project had reached more than 80,000 rural families who had planted more than **twenty** million trees on their land.

As of this date numerous formal evaluations have been carried out (Balzano 1986; Buffum and Buffum 1985; Conway 1986; Grosenick 1985; McGowan 1986). As with all projects there have been snags and shortcomings. But the success enjoyed by the project in reaching -- not only physically but also motivationally -- an unprecedented number of Haitian farmers has led many observers to consider it a breakthrough.

Conclusions

What has been presented in this paper is an explicit attempt to facilitate the emergence of a modified land use technology. If one had to select three characteristics of a successful technology diffusion project on the basis of the experiences learned here, the following might be the most important.

Evolutionary. It would be based on evolutionary principles. That is, it would assume a preexisting technological system already in use among the intended user population. The parameters of the preexisting system create evolutionary "windows of opportunity" and evolutionary constraints. The new technology should be examined item by item **in the light of the preexisting technical system** in use among the future users.

Sensitive to user agendas. Tree project designers are often fervently dedicated to ecological agendas. Caribbean users are more concerned with **short-term micro-economic agendas.** The designers of the new technologies have to have the anthropological capacity to envision themselves in the life-circumstances of the intended users. This may entail certain technical sacrifices -- e.g. bench terraces might have been a better soil conservation device than wood trees -- but the results will be a much more rapid spread of the technology. The resulting project will be a compromise between the agendas of the users and the agendas of those introducing the technology. In that light it is useful to note that the key information on whose transmission the success of the project depended was not the (fairly simple) **technical** information about how to plant and care for the trees. What excited the farmers and motivated them to participate in numbers far exceeding our earlier expectations was the critical **legal** information that they, not the government or the project, were the owners of the trees, and the **economic** information about how much income a farmer could expect from planting several hundred of these trees.

Depoliticized. The institutional delivery channels should be chosen on the basis of their ability to carry out project objectives. This common-sense observation is often ignored in those technology-transfer projects that occur as part of "foreign aid". Prevailing institutional custom assigns the bulk of "development funds" to host-country governmental agencies, a custom that has arisen more out of political expediency than out of any positive track record which these institutions have developed in terms of effectively serving their client populations. In this paper I have explored the option of non-governmental resource channeling mechanisms that produced results astronomically superior to those that would have been achieved by any governmental institution in the Haiti of the old regime.

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THE 'ROAD THING' AND THE NEMESIS OF THE ZOWO: TECHNOLOGICAL TRANSFORMATION AND THE SEARCH FOR SELF IN LIBERIAN POETRY

Joyce H. Scott

> *And how am I to face the odds*
> *of man's bedevilment and God's?*
> *I, a stranger and afraid*
> *in a world I never made.*

Psychologists and sociologists, like A.E. Housman in the lines above, have consistently underscored in their research this attitude of alienation and loss as characteristic of the lives of modern man. Questions of who am I? Where am I going? and Do I belong? are crucial ones for all individuals in the 20th century. The artist, the muse and seer who heralds the spirit of the age, in particular faces a crisis of character and conscience as s/he grapples with the transformations occurring in his/her society, specifically where the changes of technology and its impact on the psyche are concerned.

Many literary artists, from Charles Dickens to Doris Lessing in England and Stephen Crane to Ralph Ellison in the United States have concerned themselves, through their literary art, with the "soul-destroying commercialism, materialistic vulgarity and generally callous rationalism of our technology-bound western culture. Yet modern technology, in the West, includes both the tradition of making and doing things and the tradition for "advancing the state of the art."[1] As they have evolved, modern technologies are culture-producing as well as culture-using socio-cultural systems.[2]

Nontechnological societies, however, because of their socio-cultural infrastructures, are not necessarily equipped to do more than "use" the technologies of the western world, and what these technologies "produce," all too often, is a transformation of great magnitude, but one that does not involve the adaptation to the local environment and the local economy. While for those of us in western society technology has regularly boasted problem-solving capabilities, this potential has not often been evident in many traditionally nontechnological cultures.

I specifically focus here on Liberian society, which has probably had exposure to western technologies longer than any other west African society in the operation of its economy and day to day state functions because of its long history of independence. Yet though this is the case, it remains a country of great paradoxes, for the vast majority of its people, who live still in the hinterlands, practice the traditions of their ancient ancestors who made their homes in the forests long before blacks from America resettled there and established the current republic.

The poet, the literary artist, is perhaps the one to feel the friction of transformation more acutely than any other. It is the intent here to examine the transmutation of modern Liberia as depicted in the idiom of poetry. It must be noted first of all that Liberia has a very long literary tradition going back to the Vai scripts, for an example of written legacy, and the ancient oral tradition of story-telling further embellished by artistic infusions from black settlers from America in the nineteenth century. The attempt here is not to explore, historically, the theme of transformation in all Liberian poetry, but rather to concentrate on some of the works of current writers with whom I came in contact while in the country on a Fulbright seminar during the summer of 1987.

The artist in traditional Liberian society (tribal villages) functioned within and was responsible to his community. In the oral tradition, the artist, story-teller, was anyone who participated in the creative ordering of the group experience. The artist could redesign the experience topically or recast it locally, but it was always dictated by social necessity, never by individual option as has been the tradition in western society, for the most part. The mysteries of the village (the "village thing") and of the forest (the "forest thing") were revealed in the secret orders and education institutions of the "Poro" and "Sande" societies.

Explanations for why things happened, good fortune, difficult births, illnesses, death and the afterlife, were handed down by the powerful zoes, the masters and mistresses of the Poro and Sande. And the story-teller was always there, reaffirming the order of things as they had been handed down by the great Chamba and always inextricably linked to his audience. The mystery of family, clan, births and marriage were inherent in the "thing," the spirit that inhabited the village. Mysteries of nature and man's relationship to it and the universe inhered in an understanding of the "forest thing," spirit. These truths were learned by the young during the many years they spent in the bush in the Poro and Sande schools.

The zowo is the most powerful force of the village. S/He has the power to turn him/her self and others into birds, trees, streams and mountains through the knowledge of magic and sorcery. A number of researchers have noted the power which the belief in magic has over its adherents, among them Raymond Firth who notes that it can inhibit technological change among those who practice it.[3] What the traditional society offers to the individual is order, stability, knowledge of self and place and most importantly, purpose.

The modern Liberian poet, then, finds him/her self grappling with the emotional subtleties and ambivalences that typify a nation struggling to reconcile itself to the external demands of the technological encroachments of the international community and the human plight of socio-cultural change. The order represented by the village, secret societies and their masters, the zowos, is under challenge by a political infrastructure whose directive is the perpetuation of itself as opposed to the preservation of the community/village/clan, and this daily struggle within the individual souls and selves of a nation becomes the "stuff" of subject matter for the poet and his/her art.

Fatu Masallie laments the disorderliness, fragmentation, alienation and loss of innocence that all too often accompanies the appearance of the 'road thing,' to wit, technological advancement through urbanization which necessitates a move to the city for opportunity, in her poem "I'm a City Girl."

I'm a city girl
See how I walk in my Swedish shoes
My mini skirt way up on my thigh
My chest high
My face painted
My lips dressed in chochee stick ...

I know nothing about interior life.
If, by mistake, I go up interior,
Mama asks me to scratch the farm,
Oh! I scream and show her my nails,
My smooth skin cannot permit it,
my curly-kit forbids it,
All because I'm a city girl.[4]

In earlier days, the speaker, as a "Sande girl" would have emerged from the bush painted in the chalk and traditional dress announcing to the village that another phase in the continuum of the clan's history was over and that their heritage would be passed on into perpetuity through the offspring which she was now prepared to bring forth. But a fragmentation of the historical collective consciousness has occurred with the moves of many village youth to the city of Monrovia. The poet's nostalgic preference for the "village thing" is underscored by Masallie's poem "Black Matu." She (the Black Matu) "walks with/red clay on her feet like shoes," as a Sande girl, "lappa covering her hips/ face painted with clay ... and body "shining like a mirror," perfumed by a "mixture of palm oil and herbs." Her natural beauty makes "The villagers, young and old, whisper about her" and the "wild beasts of the forest admire her," as "the hawk on the tree top flies down and bow(s) to her beauty."[5]

Liberian poets speak too of anguish and loss of spiritual integrity as the individual is beseiged by desires for the material goods of western culture, the "kwi" things that fascinate with their power to offer variety and difference. Sylvannus A.L. Tucker conveys this dilemma in "Bowls of Dumboy" as the speaker slowly learns to dislike a staple dish of his village:

> Yesterday/Mother prepared me dumboy. I loved it. /This evening/Mother prepares me dumboy/I see it./I hate it./I will hide.[6]

Noting the ills that urbanization and capitalism have spawned in the city of Monrovia, Althea Romeo-Mark writes of the problem of the beggar, a phenomenon unknown in the traditional village.

> She/was old,/a wrinkled,/sagging/bag of bones,/and she/was sitting/on the sidewalk/begging./and/I wondered:/somebody's/mother,/sister,/aunt,/yet/ nobody claimed her.[7]

The elderly occupy places of high esteem, of great respect. That such a one could come to dishonor is of concern to the poet and to many others in Liberia today. The loss of place and identity in modern technological society is further portrayed in Romeo-Marks' poems "Been Gone Too Long" and "I Am of Two Worlds." The duality referred to by W.E.B. DuBois and other Afro-American writers as being characteristic of black existence in the United States becomes also a nemesis of the modern African state.

The speaker, alienated from his culture altogether, speaks to the inconsistency of having been sent "to the city to become noble," in "I Am of Two Worlds," yet having grown apart from his people as they "greet (him) with silent smiles of admiration" today and he sits and "eat(s) politely of their offerings." As "silence permeates the air/ (he) take(s) (his) leave." Yet in the city, he is "alone between masses of people and buildings" who "do not feel (his) presence" and do not speak to him. The city-dweller is one who has "Been Gone Too Long," who has adopted the ways of the white man. He can no longer "share the hospitality of (the) hut."[8]

The theme of alienation and fragmentation is continued by Bai Tamia Moore in "Poo Boy." He observes that his "friend, poo boy, grew up in the village/eating our little dry rice/and roasted ants and breadfruit stew." But Poo Boy, like so many other Liberian youth looking for opportunity, "went to the big U.S.A./and persevered ... slinging hash and hopping bells/in frat houses and beach resorts." Though he has obtained an education, having earned "a BSc, MSc and strings of testimonials/ eh bye seemingly poo boy had lost his mother 'twang/the high-life and the gbeima/which stood him out among the dancers in the village square" in days gone by. Now, "He wiggles and snaps/sways and swags and hobbles out/of step when the drums and kongoma beat."[9]

In the ancient days Bai Tamia's people, the Vai of Timbuktu "spent all their time in reveling in oriental splendor, on the wings of magic carpets." However, "the 20th century version ... rigged with jet propulsion pods, can now cover just in hours/worlds which Ali Baba never dreamed of." This loss of the zowo's magic to the mindless power of the nuclear age is further lamented in Moore's "Ninety Plus," as the speaker struggles frantically with the conflicting realities of tribal culture and modern Monrovian facts of automobiles and other power machinery.

driver!
eh man
you don't know me
for true
a pack of brainless
        power
on four wheels
all the flashy
chrome and gadgets
rigged up
on the pannelboard
        automatic
this and that
futoramic drives and all
all of it is pamba (naught)
you push
    a button
pull
    a switch
off we go
  faster
than a jackass
30 - 30 - 60 miles
85 - 90 plus bang!
gbongoso! gbangasaa!
    Bang!
and to hell we go ....[10]

Bai Tamia Moore continues to reflect on the insecurity and loss of personal worth as technological power of "the road thing" brings with it more "kwi" objects of mechanical power which strike awe into the souls of the simple Liberian peasant in his poem "The Bulldozer." Here the machine, which is personified, is the source of destruction as it "chew(s) up concrete walls/and knock(s) down mango trees." Yet like the powerful beast which modern technology has sometimes become, the bulldozer's "Belly's never full." The speaker goes on to note that it "leave(s) (the) wives with harried nights ... and hush(es) (their) high-life music." The displacement felt is starkly portrayed in the closing lines of the poem as the speaker says, "We are the squatters/We are the lot/Who keep forever wandering/looking for a piece of land that we can call our home."[11]

Gamu Woiwor compares Liberians uprooted by the march of industrialization to crabs along the shores of the Atlantic in his poem "Crabs, How Do You Do?" He wonders how they, "subjects of the whale: Taxed forcibly ... outrightly defrauded" are faring. The metaphor is extended to encompass the daily struggles of Liberians in that their "children crave an education," thus "surely, (they) can't afford/the new holes (they) fancy." But the speaker shows optimism in the face of what seems to be overwhelming odds by contending that "Were I in your predicament/My oppressors would be taught/That even clams have power;"[12] the zoe still has magic.

Writing about the plight of workers constructing the Bomi Hills railway, Bai Tamia Moore further echoes the great sacrifice exacted from Liberian villagers for the benefits of technological advancement. In the poem "Thirty Cents," the speaker bemoans his condition as he "toil(s) all day for thirty cents/with which to buy a lapa,/A cup of rice and palm oil/For Saata, Trybest and (himself)." Wise now to the deception which lured him away from his village, he recognizes that the price for progress has been too great:

Was it for this I left my home
To which some day I must return
With weakened bones and pidgin tongue,
Devoid of all that birth bestowed?

Was it for this I left my kraal
And all the virtues of my tribe?[13]

The Poro and Sande societies defined for the individual his role in the village. The kind of working environment to which the poet refers in the poem is one which produces a spiritual improverishment while making way for the operations of industry and mechanization. While some problems are solved--the ones of transporting people and goods--others are created and are, perhaps, unsolvable.

From beautiful Black Matu of the Sande society in her village, the young Liberian girl too often becomes a waif of the streets in the city of Monrovia as Bai Tami Moore's poem "Grona Girl" reveals, a loss of innocence never to be regained:

grona girl
ba
that's me
the big society
people
the big shots
know me
by that name
some even
jeer at me
or turn
their noses
when I pass by
in the streets

my grona
plawa
came on like
a nitemare
they baited me
with plenty things
a 50.00 flat per month
a big refrig
a jantzen double bed and
springs .....
I knew not what it meant
to be heckled
like my sisters in the
market
fathers of perhaps
some daughter in
a distant land
stood over me
my naked body shivering
I heard them say
the s.o.b. is sweet
but a grona girl[14]

Societal transformation brought on by the pressures of the international community are many in Liberia as in other African countries. The double-bind for the individual confronting the forces of change and the pull of his/her community is ominous and destructive in many cases. As Moore notes in "Grona Girl," the decision to leave the security of the village and its defined place for each person is often necessitated by basic material needs no longer supplied through the traditional network of the community and the power of "the village thing." Althea Romeo-Mark's "Decision" bears out this observation, as the speaker confirms that "she gave/it all up/for a lappa suit." And "now she bears/the seed of a man she never/really knew 'cept he came/from America/and had/a lot of money and made many promises."[15]

The final summation of Liberian poets' response to the fast-paced changes in their society brought on by technological advances has not been rendered here; rather the aim has been to shed light on a dilemma affecting emerging nations whose traditional cultures are at odds with western mechanization but whose future -- because of its past -- is decided interwoven with that of the rest of the industrial world.

The sensibilities of the artists, as it is contended here, are most often the first to be assailed by the paradox created by his/her society's transmutation from the old to the new. The artist's role in Liberian society has undergone a marked change from its ancient function. His/Her role as part of the mystery of the village and the forest "thing" is being redefined by the reality of the "road thing" of industrialization. Even his/her medium of expression (in the oral tradition) has been transformed by the introduction of print media, thus the phenomenology of the creative experience as it is conveyed to others is decisively altered. What forms the new artistic expression, as well as the new Liberian emergent national culture, will ultimately assume is yet to be revealed. Althea Romeo-Mark, perhaps, says it best in "Transition":

> *When bulldozers*
> *bring civilization*
> *the age of innocence*
> *quietly takes its leave.*
> *It is buried*
> *under the dirt of progress.*
> *There will be memories,*
> *dreams, glorification of*
> *a nebulous past.*[16]

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SCIENCE AND TECHNOLOGY IN CONTEMPORARY LATIN AMERICAN LITERATURE: A MORE COMPLETE HUMANITY

Ted Lyon

In a (1924) poem dedicated to the "working class of Mexico City," Manuel Maples Arce exults:

> Oh City all tense
> with cables and work,
> All melodious
> with motors and wings.
> . . . .
> Oh strong, complex city,
> Built with iron and steel
> The docks, piers, cranes,
> And the sexual fever
> of your factories.
> . . . .
> O musical city,
> music from mechanical rhythms.

(Maples Arce, part 1; my translation)

The poem represents a literary movement known as Futurism, or praise of progress and the marvelous motor.[1] In Latin America the movement often linked with Marxism to create a eulogy for all technological development created by the working class. This praising attitude toward science and its resulting technology is reminiscent of Walt Whitman's "Ode to a Locomotive in Winter," or scores of other writers of the late nineteenth or early twentieth century. But the later twentieth century, especially in Latin America, often mistrusts and even fears technology and its effects on humankind. There exists among most Latins the obvious desire for the products of comfort, beauty, and health that technology creates but contemporary literature expresses serious doubts about the ability of science, with its rational, empirical methodology, to produce lasting positive results for human beings. The poem by Maples Arce is now an anomaly. More representative

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[1] Futurism as a literary movement, has its origins in the Italian Marinetti, who issued its first poetic manifesto in 1909. Merlin Forster best traces this rather short-lived but intense movement in Latin American in his Historia de la poesía hispanoamericana. Federico de Onís also explores the movement's chief communicants. See bibliography to this paper.

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are the comments of one of Latin America's most acclaimed new novelists, Isabel Allende. In a recent interview she affirmed.

> In my life, I try to be alert and capture my surroundings through *emotions*, *feelings*, *intuition*. I make fewer mistakes this way than when I use reason alone. . . Scientific and technological development, especially in the Western world, has kept us from paying attention to our instincts or our spiritual nature... reason is not sufficient; there now exists a desire to find other paths [to knowledge].
> Every day the developed countries of the world invent new technologies... and sell their leftovers to us, the Third World (Moody 57, 58; my translation).

A Chilean poet, Waldo Rojas, recently stated that "Science cannot prove a thing relating to what is truly human about us--memory, thinking, or *why* I write poetry.... Life is more mystery than logic and order" (Rojas).

Why would this anti-scientific, anti-rationalistic attitude prevail among many Latin American writers when there are so many progressive benefits resulting from reason and science? Mexico's political history may serve as a model to demonstrate the background for this feeling. After the chaotic years of independence from Spain in the first part of the nineteenth century, Mexico suffered through frequent and ineffective leaders. Liberalism had produced revolution and independence but not stability. Finally, in 1876 Porfirio Diaz took power and "served" (up) his country for thirty-five years. Diaz was a card-carrying positivist and surrounded himself with a group of intellectual followers of Comte, known as "los científicos," or, "the scientists." These "scientists" were a type of "progressive conservatives" (Torchia Estrada 147). Positivism, at least in Mexico and Latin America, was a philosophy of order, seemingly necessary to emerging nations with too little leadership experience. It joined with Darwinism in Latin America in its emphasis on scientific *observation* and *data* collection. Through positivism and its methods, "inequalities were now explained, not by race or inheritance or religion, but by *science*" (Paz 131). Yet the emphasis on order and progress did not lead to prosperity, to equality, nor to happiness. Octavio Paz views positivism in Mexico as "the heir of colonial feudalism" (Paz 130). The government "scientists" easily demonstrated that larger landowners could produce more than family farms and hence land ownership was again concentrated in the hands of an elite few; "the past returned, decked out in the trappings of progress and science." (Paz 130). But the policies of positivism did not produce progress; they restored the past and resulted in the tragic but cleansing Mexican revolution of 1910. During thirty years of positivism, Mexico had opened its doors to Anglo-American capitalism. Mexico's mines, railroads, oil, and industry in general were developed by foreign *interests*. Frustrated Mexicans used a different term--*exploitation*. Hence, the science and technology that Mexico saw resulting from positivism became undesirable and exploitive.[2]

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[2] To date the single most comprehensive study on positivism in Latin America is Zea's *El positivismo en México*, published in 1942. Zea

Positivism, which was short-lived in Europe and Western thought in general, flourished in much of Latin America. Finally, with the advent of the First World War in which the technologically-advanced countries of the world were engaged in trying to kill each other, Latin American countries could and did reject the movement. They could now easily say, "See, the countries where science is so advanced are so obviously decadent that they bring much of the world to battle; we'll develop our own higher moral and human values." Hence, many of Latin America's intellectuals departed from praise of the machine and sought to develop more humanistic values. Numerous anti-positivist philosophers, especially in Argentina and Uruguay, united to blaze anti-technological pathways into the twentieth century.[3] This philosophy, coupled with a history-proven mistrust of North American power, continues to influence Hispanic artists.

Brief examples from four representative contemporary Latin American writers demonstrate a critical and common attitude toward technology. The most obvious is Mexican short story writer **Juan José Arreola** (1918). "Verily I Say Unto You" ["En verdad os digo"], a 1951 story, recounts the supposedly altruistic attempt of a scientist, Arpad Niklaus, to pass a camel through the eye of a needle. Naturally all the wealthy of the world are interested since the success of the experiment will make it much easier for them to get into heaven. Arpad writes a fine proposal which is of course approved by regional and national committees, and the scientist then begins his work. In pseudo-scientific language, Arreola convinces the reader that Arpad's most promising approach is to break the camel down into its individual electrons and pass them through the needle's eye and then reconstitute the beast on the other side. The author informs that even humane societies have approved the project since it will likely produce a regeneration of the animal and a longer lifespan. The experiment however, is *very* costly, and in modern parlance seems to have inevitable "cost overruns." But no mind; if successful, the rich will indeed have a place in heaven; if not, "the rich, impoverished in masse by the draining investments [into the research], will easily enter in the kingdom of heaven... though the camel may not pass through" (Arreola 67). The irony is delightful--absurd scientific research on an obscure Christian metaphor siphons off all the money of the rich to the point that their new-found poverty permits easy entrance to paradise! What a triumph for science. Perhaps science itself is not the brunt of the criticism; the naive attitude that technology can solve a purely human, religious problem is Arreola's real focus.

A second story by the same author, "Baby H.P. " appears as a radio advertisement. Haggard housewives are urged to "convert your children's vitality into motor power. We now have on sale the marvelous Baby H.P.," an instrument that can be fastened on a child's back to harness, convert, and store his movements into usable electric energy. Again Arreola throws in an occasional scientific term (Leyden bottle) to convince the reader/listener that this is a scientifically sound apparatus. The energy stored in Baby H.P. can run the family

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noted that the adoption of positivism as the official national philosophy was a necessity, at least at first, to check the anarchy of previous Utopian thinkers. Octavio Paz (*Labyrinth of Solitude*) found inspiration for many of his ideas in Zea.

[3] For a more complete survey of this attitude, see my "El engaño de la razón: Quiroga, Borges, Cortázar, Viñas," *Texto Literario* (Veracruz, México), II, 4 (1976), 116-126.

refrigerator; large families may even create a lucrative business by selling excess power to neighbors. However, the announcer who reads the advertisement too casually dismisses rumors that Baby H.P. may malfunction and electrocute the child, and only lightly denies that children using the apparatus may attract lightning! Even though this story was written in Spanish for consumption in Mexico, the title is in English; the "H.P." refers to horse power, and the manufacturer is a J.P. Mansfield and Sons, of Atlanta Illinois; Arreola here points to the country from which much of Mexico's technology originates. In its exaggerated way, the story affirms the common Latin American view that much technology tends to dehumanize; in this case the greedy purchaser would be using his children as machines to keep the lights on, rather than accepting them as active human beings to be nurtured, enjoyed and loved. Several other stories by the same author reflect similar negative views toward the uses of technology.

Argentina's **Jorge Luis Borges** (1899-1986) is more subtle than Arreola. He does not pit a scientific gadget against a human but attacks the epistomological bases of science--reason and logic. For Borges, the world, the universe, and especially the human mind, are simply too complex to be apprehended by reason and analysis. Borges, of course, is not alone in this skepticism. Bertrand Russell (*Skeptical Essays*, *The Analysis of Mind*), Alfred North Whitehead (*Process and Reality* and Jean Paul Sartre (L'être et le *néant*, *Critique de la raison dialectique*) would find a brother in the Argentine writer. In Borges' stories the life of an individual, language, history, modernity, indeed the entire universe, may best be symbolized by an impenetrable labyrinth. Science can never hope to decipher them completely, and those who use reason alone are bound to hopeless despair, forfeiting their lives or their sanity.

The most obvious example from his stories is detective Lönnrot, the "pure reasoner," in the parodic detective story "Death and the Compass" (Borges, *Labyrinths*, 76). Instead of accepting the obvious details of a crime, a case of mistaken identity, he creates a complex plot in his logical mind. His profound thinking allows him to figure out precisely when and where the next murder will occur. He confidently goes to the spot to apprehend the murderer, but only too late does he realize that his reasoning powers have set the trap for him--*he* is the final victim. Had he simply accepted the obvious he would have easily saved his life. Digging too deeply into history and creating a complex mathematical model brought self destruction.

Many of Borges' best stories poke fun at those who live by reason alone. "Ibn Hakkan al Bokhari, Dead in His Labyrinth" pits a poet against a mathematician as they attempt an explanation of a murder. The poet, Dunraven, explains Ibn Hakkan's death as mysterious and mythical but this explanation does not satisfy his mathematician friend, who begins a logical interpretation that soon becomes so complex and absurd that he loses himself (and the reader too) in his own labyrinth of words. His "explanation" is no more accurate than the mythical one. The author's comments are revealing; Borges states, "When I wrote 'Ibn Hakkan' it became a cross between a permissible detective story and a caricature of one.... What I ended up with I hope will be read for its humor" (Borges, *The Aleph*, 274).

The most tragicomic character in all of Borges writings is "Pierre Menard, Author of the Quixote." Menard is a scientist of language and decides that he must re-write the novel *Don Quixote*. To do so requires years of arduous mastery of seventeenth century Spanish, fully understanding and living the norms of the day, a complete knowledge of world politics, history, etc. He also had to "recover the Catholic faith, fight against the Moors, forget the history of Europe between 1602 and 1918," and simply be Miguel de Cervantes (Borges, Labyrinths, 40). After years of Herculean effort Menard is successful, and rewrites the complex novel, word for word with the original! Obviously, Borges is poking fun at Menard's organized folly, and summarizes by saying, "There is no exercise of the intellect which is not, in the final analysis, useless" (Borges, Labyrinths, 42). Borges does not attack the scientist nor eschew his machines; rather he questions the base of science, reason and logic, doubting whether truth can result from purely logical investigation.

With an insightful gift of observation, Chile's Nobel poet, **Pablo Neruda** (1904-1973) writes of his country, his continent and his deep feelings. Poems in Elementary Odes generally praise the simple natural things of the world and the joyous fruits of the earth. Here Neruda extols friendship, compassion, love, as well as onions, socks and celery. He applauds the primitive elements of the Americas, and quite understandably sees United States technology and industry as exploitive and dangerous.

The United Fruit Co.

When the trumpets had sounded and all
was in readiness on the face of the earth,
Jehovah divided his universe:
Anaconda, Ford Motors,
Coca-Cola Inc., and similar companies.
The most juicy item of all,
The United Fruit Company Incorporated
reserved for itself the heartland
and coasts of my country
the sweet mid section of America. (Neruda 79)

Neruda continues the poem with an indictment of technological power that has protected dictators who then protect U.S. interests in Central and South America. These dictators are "flies, flies/dripping with humble, marmalade blood." North American development, suggests Neruda, has created a rubbish heap of pristine Latin America. The words may not be objective but the attitude truly reflects the feelings--North American engineering, technological agriculture and management have perverted more natural ways.

Yet Neruda also looks at the materialism of his own country. In one of his best-known surrealistic poems, "Walking Around," he anguishes,

It so happens that I am tired of being a man.
It so happens that I walk into tailor shops and movies
withered, locked in myself, as a lifeless swan,
drifting on waters of origin and ash.

The odor of barbershops makes me cry aloud.
All I ask is the sleep of rocks, or wool,
All I ask is to not see businesses and buildings,
Nor merchandise, nor eyeglasses nor elevators. (Neruda 29)

Buildings, elevators, and man-made institutions bore and bother the poet. His yearning for peace and communion will not be satisfied in the modern world of things. A more complete humanity would result from spiritual communion with the native past, as he expressed in his marvelous poem, "The Heights of Macchu Picchu."

Latin America's best known novelist, Colombian **Gabriel García Márquez** (1928) joins with Arreola, Borges, and Neruda in his concerns about technology. Jane Robinett has already presented a fine discussion of García Márquez's One Hundred Years of Solitude in the Bulletin of Science, Technology and Society (see bibliography). The following commentary, brief because of Robinett's accurate analyses, adds insight not present in her work. One Hundred Years of Solitude is a fanciful account of the Buendía family in the mythical town of Macondo. The story begins in a Garden of Eden-setting. "The world was so recent that many things lacked names, and in order to indicate them it was necessary to point" (García Márquez 11). Or, "It was a truly happy village where no one was over thirty years of age and where no one had died" (18). A band of gypsies bring simple inventions from the developing world to the isolated town and it gradually becomes corrupted. At first elementary scientific instruments--magnets, magnifying glasses, chemistry sets--almost children's toys--come to town. A simple block of ice is hailed as "the largest diamond in the world" (26) and hyperbolically but naively as "the great invention of our time" (26). These unsophisticated scientific gadgets lead the men to seek power and political control. The women continue with the simple stability of the town but the men convert the new-found technology to their advantage--alchemy, weapons and war. The guileless society loses its innocence; the train arrives; phonographs and telephones quicken the pace. Soon, and almost inevitably, the North American gringos arrive to exploit the fine banana-growing land. "Endowed with means that had been reserved for Divine Providence in former times, they changed the pattern of the rains, accelerated the cycle of harvest, and moved the river from where it had always been and put it with its white stones and icy currents on the other side of town, behind the cemetery" (García Márquez 214). After scores of other rapid and dehumanizing changes, "the old inhabitants had a hard time recognizing their own town. 'Look at the mess we've got ourselves into,' Colonel Aureliano Buendía said. . ., just because we invited a gringo to eat some bananas'." (García Márquez 215). Technology is not the culprit, rather man's (and not woman's) inability to control himself in technology, and North American greed or need to develop industry. Science here separates humankind from a lost pristine purity and allows man to abuse nature and fellowman. García Márquez does not advocate some type of a mystical return to pre-plow days, but merely laments the inability of modern man to properly use scientific invention, to maintain his former "human-ness."

Latin American literature is not alone in its doubting and criticism of empirical data, technological development and science.

> In most contemporary literature, the dominant attitude to technology...is one of hostility, which often takes the form of rejection and withdrawal. The disadvantages of technology, the fear of the possibilities that science may reveal, seems to take precedence over the good things.
>
> In most of the countries which are going through their industrial revolutions today, the technology is imported rather than developed within the society itself. The attitudes of their literary intellectuals are coloured by that fact (Morrison 120).

In reality every sensitive person has moments when he becomes suspicious or even curses machinery: the computer that "swallows" the whole article you were writing, the answering service that sweetly informs that "I am not home right now but if you will leave your name and number after the beep I will get back to you as soon as possible," when you, the caller, know darn well that Molly is home; the $12,000 car that won't start because a sixty-seven cent wire has come loose, or, the lousy soda pop machine that just "cheated" you out of a quarter. Writers in Latin America, and indeed most other countries of the world, have tried to capture these moments of frustration and anger which result when technology controls, frustrates or limits too much of contemporary life. Yet many, especially in the United States, see technological development as a deus ex machina solution to Latin America's problems of poverty, overpopulation, disease, and most other problems. So, one may ask, why do many of the area's intellectuals eschew the machine? Is it a "sour grapes" attitude? "If we (in Latin America) can't come in first we won't even get in the race?" No! There are multiple reasons for the prevailing attitude.

First, as Morrison suggests, much of the technology is imported and doesn't "feel" quite right. In the morning a Peruvian may shave his face with a "gilet," brush his teeth with "colgate," blow his nose with a "Klinex," and eat a bowl of "corn flakes." He will then ride a "Blue Bird" diesel bus to the office, work on an "I.B.M." computer all day and call home to talk with his wife on a phone system set up by A.T.& T. He quickly learns that his country didn't or doesn't develop those products. And despite living in and around poverty, he is fiery proud to be a Peruvian. He associates science and development with North America and Europe, areas that have dominated parts of his life and country. He also knows that many of the best minds in his country have fled to the U.S. where research grants are much more lucrative. Contemporary science is basically a "Western" phenomenon, and the contributions that his non-Western Indian ancestors made to medicine, social planning, astronomy, calendaring and many other areas, are ignored, or, more likely completely unknown. Besides, he can point to many problems: the "Green Revolution" failed in much of Latin America, largely because its technology came from abroad and did not "fit" the area. "Science is not neutral: it is history and social experience" (Goonatilake 139); if technology negates, contradicts, or even merely ignores his culture, his socio-historical reality, he may reject it altogether, without seeing its many positive aspects.

A second reason for rejection may be the pride and arrogance with which the invention arrives. A Latin American learns early that pride is one of the Seven Deadly Sins. Overwheening pride, or arrogance, is suspicious and despised in his culture. Science has come to him with the assumptions that he has a problem, that his problems are soluble by superior people and technology and that hard, organized, rational work will result in improvement (Ehrenfeld 16,17). His experiences, however, will likely cause him to doubt the result. He is almost sure that somewhere irony will enter and the desired effects of foreign technology will wither in his hot sun. He has learned to question any plan that is cock-sure it has the ultimate truth. Hubris, that old literary device that punishes arrogance, will surely enter. The Latin American approaches his world with a tentative, more humble attitude knowing that despite much data collection," we can never know the present completely," nor make errorless deductions from what we know, or at least think we know (Ehrenfeld 65). The only sure way to full human knowledge is through experience, humble and slow. Others may become anxious at the paucity of change but the Latin will not immediately trust a self-assured scientist to provide the final solution. He feels that there are some great metaphysical questions that science does not, or cannot touch: What happened before the "big bang," for example? Was there time before the start of the universe? (Goonatilake 167). Or, quite simply, what is the essence of being human? These problems are perceived by the artist not the scientist. Borges, for example, writes of these concerns, not with any scientific solutions but merely to affirm that they are problems and will remain such despite any effort to resolve them.

Much of Latin America's historical development came from Spain, the European country that has made great contributions to art and literature, but much less to Western science. Despite its openness to Arabic knowledge during the Middle Ages, Spain never developed a strong scientific tradition similar to that of England, France and the Germanic states, from the 17th century to the present. Américo Castro explains that "To the Spaniard it was not important to scientifically investigate the things we see and feel [in the New World]. . . he did not [even] pretend to know reality; he wanted to possess it fully and wholly" (Castro 7). Possession rather than understanding was the goal. Ortega y Gasset, Spain's fine twentieth century philosopher, made a distinction, in Spanish, between inventions and what I will have to here call technological invents. Scientific inventions (plow, wheel), grew out of natural human needs; technological invents (hair spray, stereo tape players) came later, beginning in the 19th century, and required the presence of a special, intelligent creator who might be removed from the item's use. This led to a society of consumers, alienated from the "proyecto vital" (life project) of earlier creators. The result has more minuses than pluses, for Ortega (Aranguren 3). This is not Marxist doctrine of alienation but rather Ortega's sincere observation that science has simply "gone too far," fostering commercialism and eventually exploitation. Latin America's spiritual heritage from Spain quite naturally bequeaths this attitude from the motherland. Spain and Latin American literature attempt to explore those realities that delve into deep human concerns, in pre-invent days. Gabriel García Márquez, for example, infuses his writings with myth and local legend, obviously feeling that they better capture the humanity of a small Colombian town than does a socioeconomic or scientific analysis of the same area.

Miguel S. Wionczek, professor in the College of Mexico, notes another possible reason why Latin American writers may question technology: "The presence of transnational corporations and the way in which the system of international patents operates, where each owner/inventor guards his own technological know how" (Wionczek 535-36). Such an attitude maintains power in the hands of the already-rich, the "haves," and, according to Wionczek, greatly inhibits economic and social development in the Third World. Quite naturally the Latin American will resent a system that seems to provide great benefits for a few but leaves him as weak and poor as ever.

Morrison notes that for most moderns the complex jargon of many scientific disciplines becomes so entangled that we feel the contemporary world slowly drifting beyond our ability to comprehend. We yearn, he says, for the supposed simplicity of the past, more natural world. Good literature may take us to that easily understood world. Morrison cites García Márquez's One Hundred Years of Solitude as the best current example, incorporating the problems that technology imposes on a less-developed society. Literature must address the challenges posed by science and if it does not "it will fail in its task of portraying the full range and variety of human activity" (Morrison 124). García Márquez has not failed. Borges, Neruda and Arreola have all engaged the world of science, reason and technology, and, for their culture, find it wanting. The world of the Latin American intellectual and artist is one of imagination, uncertainty and playfulness. May science and technology not choke out the irrational, delightful elements of Latin American life and literature, indeed, our humanity.

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RELIGION IN ASIA AS A VEHICLE FOR TECHNOLOGICAL CHANGE

Fred R. von der Mehden

Social scientists have generally perceived religion as a hindrance to technological change. While noting that there are times when religion plays that negative role, this paper concentrates on religious elements that have had a positive impact on modernization in Southeast Asia. These are analyzed on two levels. The first is the role of religious beliefs and practices in terms of religious personnel, education, expenditures and specific tenets. The second area of analysis covers efforts by governments and organizations to employ religion to legitimize modernization projects. It is argued that these attempts may fail if the manner in which religion is employed is unfamiliar to the people or appears to be too manipulative, but can be more successful if combined with attacks on the perceived enemies of the faith and gains the support of religious personnel.

The consensus among twentieth century social scientists, at least until recent years, has been that religion almost always has acted as a hindrance to the process of modernization and modernization hastens an almost inevitable movement toward secularization. While not denying the negative role religion has played in modernizing contemporary societies, this paper will target some of the positive effects of religion in economic and social development. The focus will be upon modernization (used here interchangeably with development) in terms of establishing conditions conducive to technological change. Because there has been all too much data-free analysis of this issue, it is important to base this discussion on identifiable data and thus this paper will be illustrated from work I have done on Southeast Asia, a region populated by adherents of a majority of the world religions, including Islam in Malaysia and Indonesia, Christianity in the Philippines, Buddhism in Burma, Thailand and Indochina and Chinese and Indian followers of those countries' faiths among overseas Asian communities throughout the area. Finally, it should be underscored here that by religion I am not simply referring to the theological tenets of the faith but also to how the religion both is perceived and practiced and even manipulated. More specifically, this paper seeks to assess the relationship of religion to technological change on two levels. The first is the role that belief and practice plays in aiding or hindering that process and the second how political leaders have employed religion as a tool to attain goals of modernization.[1]

Prior to focusing on the central issues of this paper, it is important to forestall some possibly erroneous assumptions that have become part of public perceptions. While this is not an analysis of religious ideology, the terms often employed by the religious activist and observer alike have led to many ambiguities. Words like "fundamentalist" and "religious fanatic" have been part of media coverage and even academics disagree on that is entailed in fundamentalism. Such differences are important, but are not central issues in this presentation. The only point that I wish to make at this time is that usually fundamentalist rhetoric, including attacks on "Westernization", does not entail a Luddite assault on technological change. In fact, many religious activists here in the United States and abroad have successfully employed technology to spread the faith. What is almost universally condemned by these spokesmen is the overemphasis on materialism and moral decay which they see as unnecessarily accompanying the Western model of modernization.

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This compartmentalization of religion and technology in the minds of many contemporary religious leaders has not always been appreciated by Western social scientists. Yet, to accept this misperception leads to characterizations of religious revivals as the "return to medievalism" and other perjorative terms.

I.

A review of the literature on modernization as well as many statements by practitioners in the field will easily provide the readers with comments that underscore the negatived role of religion in the modernization process. As I have commented elsewhere, "To Comte, Spencer, Marx and other intellectual giants of the nineteenths century, religion in general was the problem, while to many in academia, the Christian church, and the general public, 'progress' was being retarded by 'backward' and 'superstitious' faiths such as Islam, Buddhism, and Hinduism."[2] A wide range of complaints have been forwarded, including charges that religion leads to "otherworldly" attitudes, religious education is stultifying, specific tenets and practices limit the ability of societies to "progress", and that religious personnel are parasites providing undesirable role models. During the nineteenth century travelers, civil servants and missionaries in the field had castigated non Christian religions as debasing the human spirit, reinforcing both the languid ways of the tropics and "backward" traditional leaders, and generally acting as a bulwark against the "progress" being promoted by the Christian white man.[3] Nor did Christianity escape such allegations. In the United States the Catholic church was a particular target. At the turn of the century those seeking "Manifest Destiny" in the Philippines saw our occupation of those islands as an opportunity to save their people for "true Christian civilization" as opposed to "heathen" Catholicism, and later social scientists saw in the church a major hindrance to "progress" in Latin America.[4]

Many of these seminal writers on modernization also asserted that the process they were studying could culminate in secularization. Some saw this as a natural and desirable result of progress, the development of a more rational universe as against dependence upon "prescientific" traditional practices and norms.[5] Certainly many would have nodded their approval to the statement by Islamacist G. von Grunebaum that "Whether from East or West, modernization poses the same basic challenge in the infusion of 'a rationalist and positivist spirit' against which scholars seem agreed, Islam is absolutely defenseless."[6] All of this added up to a severe indictment of religion as anti-modernization and established in the minds of many scholars a dichotomy between religion and progress.

II.

There are, of course empirical underpinnings to the view that religion can hinder technological change and, while this paper will concentrate on the positive role of religion in this area, it is important to recognize some of these factors.[7]

Religious Education: Where religious education concentrates upon the regurgitation of memorized scripture, particularly in non indigenous languages, it hampers the ability of students to operate in a modern technologically based society. This is particularly true of Theravada Buddhist schools where the scriptures are learned in Pali and Muslim education in non Arabic speaking countries where young children learn to recite the Koran in what to them is a foreign language. Traditionally, these schools taught little in mathematics, geography or history. Not only could this type of learning lead to lost time for learning more "practical" skills, but it usually has not provided a sound foundation for further more "worldly" training.

Religious Personnel: It has been argued by secularists that religious personnel, monks, priests, etc., are parasites who perform no "useful" functions in the society. It is charged that they produce no productive goods, even in their teaching. In Theravada Buddhist countries such as Burma, Thailand and Sri Lanka monks and novices have at varying times totaled some half a million in a given year. To the extent that there is large-scale unemployment or underemployment, or where the clericals number a relatively low number, as in Roman Catholic societies today, one can question the real impact of this "loss" to the community. However, particularly when the clerical life attracts the "best and brightest" or its members are role models for achievement-oriented youth, there may be negative influences on technological change.

Religious Expenditures: There has been considerable research on amounts of time and fortune given for religious purposes in peasant societies.[8] The results show that peasants often spend a considerable portion of their income for feasts, purchasing artifacts, building and maintenance of mosques, prayer houses, temples and churches, support of clerics, and other religious purposes. It is argued that, if technological change is desired, these funds could be better spent on agricultural innovations, education of their children, and other more "productive" activities. In addition, this is not only an expenditure of money, but a non utilitarian use of time.

Specific Religious Tenets: Particular beliefs are said to lead to practices that hinder the process of modernization. Thus, critics point out that, for example, prohibitions against taking of life in Buddhist societies may hinder the elimination of agricultural pests or maintenance of good health practices, religious factors have led to the proliferation of cattle of dubious utility in India, and fasting in Islamic communities during the Ramadan month (Muslims are not to eat or drink from sunup to sunset) drains the ability of believers to fully employ their capabilities. It should be noted that every religion has some practice that have been criticized as inhibiting the attainment of rational goals of "progress".

III.

The thrust of this paper is that the relationship of religion to modernization (defined in terms of technological change) is a far more complex one than earlier elucidated by social scientists. My own acceptance of this complexity arises out of evidence that religion is obviously not a hindrance to all believers, it shows capabilities of being employed as a vehicle to move populations toward change and even the negative elements previously outlined have their positive attributes. Allow me to address the last point first. Accepting the argument that education, expenditures, religious personnel and specific tenets frequently have hindered modernization, the following considerations either ameleorate or counterbalance each factor.

Education: While a good deal of traditional Islamic and Buddhist education was not an effective vehicle for attaining technological change, there are at least two aspects of religious education that would appear to have had an opposite effect, i.e., Christian missionary efforts and contemporary Muslim and Buddhist efforts to integrate modern demands with religious schooling.

Christian missionary work in Southeast Asia had two positive effects upon modernization which were also apparent in other regions. Their schools frequently became the means of transmission of both Western education and specific technology. In contrast to the traditional indigenous religious schools, they provided the skills and approaches to problems that allowed their students to compete in a more modern society. Elite missionary schools became the centers of learning in many colonial systems and their students often included future leaders of the post-independence era, many of whom were not Christian themselves.[9] In addition, the missionaries were often the first to introduce printing presses, modern medicine, farm implements and sewing machines and to teach the people how to use them.

The second noteworthy impact was upon the educational patterns of Islamic and Buddhist educational institutions. Christian missionary schools and organizations became the models for those interested in amalgamating aspects of modern skills and thought with religion. In part, these attempts at replication were protective measures to meet the competition presented by the Christians, both in terms of retaining students who might otherwise go to missionary schools and defending the faith against Christian proselytizing. In the latter case, it was argued that, if Islam or Buddhism were to be able to meet the challenge of the West, it was necessary for the faithful to have the tools needed to compete (an argument that was to be used by later development-minded political leaders). From this impact came such organizations as the Muhammadiyah in Indonesia that sought to modernize Islamic education and the Young Men's Buddhist Association in Burma, an early nationalist movement deriving its inspiration from the Young Men's Christian Association.

A second major positive impact of religious education could be seen in the transformation of many traditional religious institutions into schools that combine teaching in more technologically oriented areas such as mathematics, vocational skills and the social sciences with religious training. Increasingly, these schools are meeting contemporary needs, although assuredly the education provided has been of a mixed quality and many schools retained their older mode. These institutions are particularly important vehicles for the transmission of modernity at two levels. They are to be found in rural areas where Christian missionary and state schools have, until recently, been scarce, thereby educating those neglected by other systems. Secondly, and perhaps most importantly, they present to the local population more familiar and legitimate educational opportunities. To the more traditional peasant the religious school is "safer", offering a moral grounding in accepted religious teachings in combination with modern skills. Not only does this mean, as has been noted by others, that the student may be more likely to be sent to such an institution, but there is some question as to whether the learning process is aided through such a traditional environment.[10]

Religious Personnel: While the majority of religious personnel give their primary and often entire attention to spiritual needs, and thus reinforce the argument as to their at least irrelevance to modernization, this is increasingly not the case. In the first instance, monks, ulamas and Christian clergy are often involved in a plethora of secular activities and mosques, monasteries and churches can be the centers of a range of educational, youth, health and other community activities. They thereby become conscious or unconscious transmission belts for change. Examples of this can readily be observed by visiting Catholic social action lay groups in the Philippines or a vital mosque such as the Istiglal Mosque in Jakarta.

More importantly for our discussions, a minority of religious leaders have self-consciously used their positions to foster technological change. Monks in Thailand, both on an individual and organizational level, have aided in development programs. As individuals they have lent their positions and given religious legitimacy to road building, agricultural innovations and health projects. I have seen the improvement of a road to a religious edifice needing restructuring characterized as an act of merit, thus encouraging villager participation. Other observers have commented on similar activities.[11]

Organizationally, monks have occasionally joined together to promote development. In the 1960s Thai monks, in cooperation with the government, launched a program that had trained religious personnel sent back to their native provinces. There they were to help villagers in constructing and repairing roads, schools, dams et al and advise on health and education. This aid was predicated upon secular as well as religious aspirations, the latter including fostering the Buddhist principle of giving (Dana), promoting religious security through national unity and strengthening the traditional role of the monk as a refuge for people in need.[12]

In the Philippines, Catholic clergy have actively engaged in a wide range of social action programs, not always with the support of members of the hierarchy. In fact, surveys of local parish priests have found a surprisingly high percentage believing that social action, including development projects, should engage the clergy and a smaller percentage starting that such projects were present in their Parishes.[13] Of course, the Church has been deeply involved in education at all levels for centuries (at the university level before Harvard and Yale were founded).

Finally, there have been less frequent efforts to gain the cooperation of Islamic teachers and preachers to participate in development activities. As one report noted, in Indonesia it has been difficult to get them to discuss extending the faith through community action.[14] However, organizations such as the Lembaga Studi Pembanunan (Institute for Development Studies) began training sessions in the early 1980s to widen the perspectives of local religious leaders.

Religious Expenditures: It is more difficult to argue the positive relevance of religious expenditures in the search for technological change. The best that can be said here is that there is no evidence that funds not spent on such activities would be employed more productively elsewhere and some expenditures appear to have positive effects. For example, life-cycle religious feasts provided a means of spreading nutritional benefits since they were often paid for by more well-to-do members of the community and included foods otherwise not regularly available to poorer villagers. Supposedly this would make the rural population more healthy and secular challenges to such feasts have apparently adversely effected villager diets. As well, peer group pressure to participate in religious expenditures are said to have influenced villagers to enter the modern commercial sector in order to obtain the necessary funds. In that sense, once the modern sector was established, such demands forced the individual to widen his or her horizons. Obviously, such arguments are tenuous.

Specific Tenets: There are two ways to counter the previous criticisms of specific tenets as hindrances to progress. It can be argued that these religions rationalized their beliefs to fit contemporary needs. Thus, an elementary health book in Burma described bacteria as vegetable to meet possible objections to killing living things. However, while we may be willing to accept Dutch Islamicist Snouck Hurgronje's argument that all religions must change if they are to remain relevant, this rationalization begs too many questions.

A more defensible position can be that while some of the aforementioned tenets may have aided technological change, others have contributed to modernization. For example, one of the Five Pillars of Islam is that every Muslim should attempt to make the pilgrimage to Mecca (the hadj or hajj). On its face this would appear to be an unproductive expenditure to fulfill a religious rite that would only fill the coffers of travel agents and rich Saudis. However, in an interesting fashion the pilgrimage has, as many observers have noted, reinforced the status of those entrepreneurial elements in Southeast Asian Muslim communities most likely to become involved in the modern sector.[15] Thus, while one source of pilgrims are older believers who have saved their money, traditionally many hadjis have been Muslim merchants able to afford the long trip earlier in their lives. Upon their return, these pilgrims frequently have religious legitimacy giving further foundation to their economic power. Since these men are often the transmission belts for modern technology into the village, as well as influential in commercializing previously more traditional agriculture and industry, they can play an important role in the process of modernization.[16]

In sum, while these aspects of religion in Southeast Asia do not present us with either a clear-cut positive or negative relation of religion to technological change, there are reasons to argue that under certain conditions they can act as a vehicle for advances in technology. In addition it is important to ask a corollary question. When we see obstacles to modernization are they due to religion or to a variety of other traditional elements that have accrued to it over time or are misinterpreted? This question becomes salient when we address two areas of investigation. First, if we look across Southeast Asia do we find people of the same faith, with an apparently similar depth of belief who differ markedly in their receptivity to technological advances? Secondly, analyzing particular cases of delayed acceptance of technology, is it possible to isolate the religious factor?

While we cannot go through a complete comparative analysis of all communities in the region, several salient illustrations give evidence to similar religious environments but differing patterns of modernization. For example, if we compare the Thai peasant of the Central Plains with his counterpart in Burma, we see two Theravada Buddhist societies. In each case there is an active clergy, extensive expenditures on religious activities and, although it is impossible to ascertain the depth of belief, external participation in religious acts are comparable. Yet, there are significant differences in the speed with which each community has accepted modern technology and been capable of meeting modern economic challenges. The Thai Buddhist appears to be far more attracted to material goals than the Burmese, and the Thai village displays far more technological innovation, although neither seems to fit the stereotypical "otherworldly!" ascetic.[17]

Similar comments have been made with regard to Southeast Asian Muslims. S. Alatas has argued with regard to their entrepreneurial spirit, which many would state was an important opening to new and wider horizons, that religion has not been a decisive explanatory factor. "The factors which released the capitalist spirit among Arab Muslims, Indian Muslims, Minangkabau, Acheh and Bugis Muslims, and also the Chinese, must clearly be of non-religious origins because (a) either they reacted in a different manner despite the same religious and mystical background, or (b) they developed a common capitalist spirit despite differences like the Indian Muslims and the Chinese and Malay."[18] The Minangkabau, noted by Alatas, are an excellent example of a Muslim group that has been very effective in competing with others, including the overseas Chinese, and have been quite successful merchants and traders in communities where fellow believers have disdained change from traditional ways.

Another method of testing the efficacy of religion as a hindrance is to investigate cases where groups have not been willing to innovate and to see what role has been played by the religious factor. From a review of a number of cases, some of which were personally observed, the only generalization that can be made is that one can't be made. There have been situations in which religion delayed change such as in the employment of insecticides in Burma and cattle improvement in the Philippines. On the other hand, there have been many cases of condemnation of religion as an inhibiting factor when, upon investigation, economic, political or non religious traditional explanations were more accurate.

For example, peasants in Northeast Thailand were frequently criticized for a lack of agricultural innovation, including a perceived unwillingness to employ insecticides, new strains of rice and chemical fertilizers. Factors supposedly influencing these decisions centered on a combination of characterizations of the Northeasterner as, to put it politely, personally "unsophisticated," and there were accusations that agricultural change in the area had been retarded by the dead hand of tradition, of which religion was a major element. Yet, interviews of these individuals found rational decision makers who fully understood that they faced a lack of capital combined with an unpredictable climate that made successful harvests a gamble. In that situation extra expenditures for agricultural innovations were perceived as chancing financial ruin. Religion and tradition appeared to have limited importance.

Or, on a more general level, observers over the years have blamed religion for what was characterized as the "lazy native." particularly in the nineteenth century missionaries, colonial civil servants, and travelers argued that Islam, Buddhism and Roman Catholicism were largely responsible for poor work habits of the local population. The "superstitious," fanatic," and "otherworldly" native was supposedly held in hie "medieval" world by his religion. Far too many of these observers gave little attention to the enervating climate, difficult health conditions, differing personal priorities and the influence of their own colonial economic and political controls.[19] To characterize the unwillingness of the Southeast Asian to accept European work values as predicated upon religious factors was far too narrow an assessment.

IV.

To this point I have attempted to analyze the interaction of religious practice and belief with development. It is obvious from what has been stated that, while the evidence is, at the very least, mixed, the complexity of the relationship brings into question the often simplistic portraits of earlier social scientists. The following section addresses another area which was not adequately assessed. It was based upon a misinterpretation of changing conditions which can easily be excused, given the apparent realities of the first decades after World War II, i.e., that the process of secularization had proceeded so far that the manipulation of religious symbols could not be expected to be effective tools to achieve development goals. It is true that at the time there was a general consensus that economic change would bring increased secularization and that religion could not withstand the challenges of modernization. However, a quick perusal of the ideas of Afro-Asian leadership and the thrust of the ideologies being fostered in the Third World appeared to underscore that process. In Southeast Asia we saw the force of Marxism-Leninism and secular social democracy in the statements of party and intellectual spokesmen. The chief political leaders of the time reflected a more secular focus as seen by the views of early nationalist leaders such as Ho Chi Minh of Vietnam, Aung San of Burma, Sukarno and Soetan Sjahrir of Indonesia, Magsaysay of the Philippines, Lee Kuan Yew of Singapore and, at least at the time, Tungku Abdul Rahman of Malaysia. All of these men were committed to national unity and economic development, including the need to catch up with the industrial world in technology. Few in those days appeared to see religion as a factor in achieving these goals and several were either secularists or feared that religion would hinder efforts at national unity.

Yet, as we will see, the ensuing years have brought forward a host of efforts to employ religion as a means of attaining development efforts. What changed? In part the increased role of religion in political life came from efforts in the post-independence years to reach out to their mostly rural populations of those countries in order to attain those twin nationalist goals of unity and modernization. As this process developed, it became obvious to political leaders that a significant portion of the people remained committed to their faiths. Thus, if policies were to gain popular approval, it would be necessary to integrate traditional concepts, including religion, into previously more Western oriented national ideologies. Secondly, political spokesmen for particular religious groups found that their common faith could be used to rally their people to attain modernity as a way of meeting the challenge of other competing communal elements. Modernization thus frequently became a facet of the defence of the faith. Finally, in part as a result of these pressures from below, there arose in many countries political leaders who proclaimed a greater commitment to religious values. All of these factors led to a series of efforts to inculcate religion into the raison d'etre for development. What follows are some of the significant attempts in that direction.

Burma: Devastated by the destruction of World War II, Burma then experienced a long civil war. Violence was to further effect the development process as the secularist "Father" of his country, Aung San, was assassinated and followed by the "monk-politician," U Nu, who became prime minister. Combining a deeply held personal Buddhist commitment with a development oriented social democratic ideology, U Nu launched a project to rehabilitate and modernize his country. The so-called Piyidawtha Plan[20] was in part presented to the people as a means by which Buddhists could both gain merit by supporting the Plan and strengthen their faith by building a stronger Burma which would, in turn, defend Buddhism. The effort eventually failed due to maladministration, a lack of funds and weaknesses in the plan itself. The religious campaign was never entirely successful, in part because it was not adequately explained and in part because it was attempting to transfer the idea of merit from its traditional individual goal to a collective one (Theravada Buddhism is a highly individualistic faith that emphasizes personal actions to gain merit).

Indonesia: For the past two decades Indonesia has been ruled by a military dominated government that proclaims as its central goal development (its head, President Suharto is called "Father of Development"). However, while the country has the largest Muslim population in the world, the majority of the people and the governing elite are infused with traditional beliefs (Agama Djawa) portrayed by the minority of practicing Muslims as of questionable orthodoxy. To the latter, the government's efforts are viewed as an expression of non Muslim concepts and as not sufficiently targeting rural areas where they reside. These twin perceptions have led Muslim groups to work toward their own development projects.

Not only is it felt that the authorities do not pay attention to their needs but that the Muslim community has special considerations and contributions. Thus, the Institute for Development Studies (Lembaga Studi Pembangunan) notes that most religious education in Indonesia revolves around faith and worship "while issues such as extending that faith through good actions in the community is <sic> barely touched upon."[21] To meet these needs, the Institute fostered programs to train religious teachers to aid in community development.

It is also argued that Islam can provide a more humane and participatory form of modernization. This argument takes two roads. The one sees religious leadership as incapable of helping the development process in a material way. "The Kiai <religious teacher> doesn't talk about development and industrialization strategy, but he does play a role in showing how to implement development in an ethical and humanitarian way."[22] The other view is given by Abduurahman Wahid, one of the most articulate Muslim leaders and a leader in the major Muslim organization, Nahdatul Ulama. He states that Muslims must develop themselves, using their own legacy and goals. he calls for an approach that targets the local level through participatory development programs, reflecting ;the people's needs, building their skills, capital and acquisition of technology, all linked to religious aspirations.[23] These proposals to combine development and religious aspirations are not simply the polemics of traditional Muslim scholars or activists, but are also reflected in the halls of academic institutions. In fact, ironically, one of the centers of new concepts and proposals has been the Technological Institute in Bandung, the so-called "MIT of Indonesia".

Perhaps the best example of a development program that meets these religio-development goals is the model pesantren (religious school), Pesantren Pabelan. Headed by a graduate of the Bandung Technological Institute, the pesantren is heavily involved in a wide range of development projects in cooperation with its home village. Its development strategy is based upon holistic philosophy emphasizing appropriate technology. According to the head, "We don't want to change to become like someone else; we want to change to become ourselves."[24] In 1984 1400 boys and girls studied courses at the pesantren in math, sciences, community development, languages, entrepreneurship and civic planning along with rigorous courses in Islam.

Thailand: In the mid-1960s Thailand was faced with increased communist led insurgency in the more remote and poorer provinces of the Kingdom. As part of the effort to control this outbreak, the Thai government, with major United States aid, launched development programs specifically targeting areas perceived to be endangered by the communists. The issue rose as to the employment of members of the Sangha (monkhood) to lend their recognized status and leadership to the development and anti-communist drive. On the positive side was the fact that traditionally the monk had often been the focus of village improvement efforts and provided a ready-made rural foundation for projects. Against their use was the primarily spiritual role played by the Sangha and the fear that such programs might politicize elements of the monkhood as had characterized the Burmese nationalist experience.

The decision was made to start a relatively small program to train monks in development issues. One part of this program was for the monk both to bring Buddhism to the "heathen" and help with development projects among the hill tribes as a means of integrating these peoples into the Kingdom. The second was the previously noted effort to use monks to aid in health and village projects to other parts of the Kingdom. These efforts had some limited success, but were not expanded due to a variety of factors including a perceived diminishment in the communist danger, traditional restraints upon the Sangha against too heavy involvement in material versus spiritual concerns, and the institutionalization of other means of spreading development.

Singapore: Among the more secular states of Southeast Asia, Singapore would appear to have a government bent upon economic development based upon being on the cutting edge of technological advances. At the same time, the city-state has experienced two seemingly disparate problems in establishing its national identity and maintaining traditional family relationships in a modernizing urban society. In the early 1980s Prime Minister Lee Kuan Yew launched a campaign to inculcate Confucian values into the system. Rationale for this was the need to support traditional family relationships, although some critics argued that the government sought to strengthen itself by underscoring Confucian principles of loyalty to the sovereign. Also noted by establishment spokesmen at the time was the need for discipline in order to carry out national goals fo unity and development and references were made to states such as the Republic of China, Japan ;and South Korea, all societies that appeared to be advancing technologically while maintaining traditional values. As, was stated by an observer in the FAR EASTERN ECONOMIC REVIEW, "Singapore's goal is to create a corporate state similar to Japan in which both government and industry are an extension of the family with all three sharing responsibility for individual welfare."[25] The program was not entirely successful as many Singaporeans viewed it as both alien to their way of life and an unwelcome intrusion of the government. Defined more in terms of an effort to indoctrinate the people ideologically rather than religiously, one critic said of Confucianism, "It breeds obedience to authority but it does not stimulate innovation or original thinking."[26]

Malaysia: Arguably, Malaysia provides the best example of a successful employment of religious symbols to aid the process of modernization. To understand Malaysian political and economic life it is important to recognize the religio- ethnic composition of the country. Approximately one half the population is both Malay and Muslim, one third are Chinese and most of the remainder Indian. The Malay-Muslims are largely rural and traditionally poorer than their counterparts, but have dominated the political and administrative life of the country. The Chinese, for their part have populated the urban centers and controlled, along with the Europeans, the commercial and industrial sectors. It has been the goal of contemporary Malay politicians to attain economic equality with their communal counterparts while maintaining political power. One weapon in this campaign has been religion.

Since independence Malaysia has been governed by a coalition led by the Malay-Muslim party UMNO whose primary commitment has been to protect and further its constituents' race and religion.[27] Development has now become a means of meeting that commitment. First, it is posited that, if the Malay-Muslim is to be able to compete with the Chinese and thereby maintain a dominant position in the society, it is necessary to gain knowledge of modern technology and to participate in the modern industrial and commercial sectors. This provides part of the ideological underpinning to the New Economic Policy, a major "affirmative action" program to establish economic, educational and social equality among the communities in Malaysia. Most particularly, it is to allow the Malay Muslim to compete with the Chinese. Secondly, as in the Indonesian case, by leading the way to modernization, the Malay leadership argues that it can diminish of "un-Islamic" aspects of Western-oriented development.[28] Interestingly enough, the Malaysian administration argues that to meet the challenge it is the Malay that must change, not his religion. As the Prime Minister stated, "Today we face the biggest struggle - the struggle to change the attitude of the Malays in line with the requirements of Islam in this modern age."[29]

In this case, religion, when combined with ethnic loyalties has been a useful tool to galvanize the Malay people into a more active role in the modern sector. Obviously, there were other factors as well, but in a society where a large number of rural Malays are entering urban areas apparently dominated by Chinese, Indians and Europeans, the disparity between the believers and "kafirs" is a constant affront to the faithful. Government efforts rhetoric and action encourage the entrance of more Malay Muslims to obtain a competitive education and become involved in the modern economic sector, but they also make such choices religiously acceptable and desirable.

A review of these and other attempts to employ religion as a device to urge the faithful to modernize and to legitimize the process as a means of defending the faith gives evidence to both the negative and positive nature of such a strategy. The less successful efforts have generally foundered upon two failures. In the first instance, the religious foundation to programs have not been adequately related to concepts familiar to the local populace. This was true of the Burmese case, where merit was made a national, rather than an individual act and Singapore, where Confucian values were rejected by many critics as out of place in a modern society. Successful implementation of this strategy could also flounder when there was question as to the propriety of government involvement in religion or its manipulation for secular goals. This factor could be seen in Singaporean reactions to the administration's attempt to inculcate Confucian-oriented values into the nation and the issue of using monks in Thailand for materialist projects rather than leaving them to traditional spiritual activities.

More effective strategies generally revolved around two concepts. First, there was the possibility of capitalizing on an apparent danger to the faith that could be met through development. In the case of Thailand, it was secular communism, easily defined as a serious challenge to the tripartite Thai ideology of "Buddhism, King and Country." In Malaysia, it was the economic and educational dominance of the Chinese, Indians and Europeans who threatened to keep the Malay Muslim as a permanent underclass in his own country. Finally, in Indonesia, the danger came from government development programs that were perceived as administered by unIslamic forces bent upon fostering materialist goals and by-passing Muslim needs, particularly in rural areas. Secondly, to the extent that local religious leadership can become involved in projects which they see as meeting their own non secular goals, such as strategy can gain a ready- made means of transmitting modern concepts and technology into previously more traditional groups. Local clerical and lay religious support has been of considerable importance for development in Thailand, the Philippines and, to a lesser degree, Indonesia.

At the same time, one should not minimize possible dangers to employing the religious tool. It can politicize clerical and lay elements that the government may desire to remain less activist with regard to other issues. The problems of highly politicized religious activists were experiences in both Burma and Sri Lanka where they provided serious challenges to government authority. Secondly, there can be severe societal devisiveness when politicians attempt to foster development as a means of meeting the challenge of other communal groups. Thus, efforts to galvanize the Malay Muslims have unsettled the Chinese and Indians in Malaysia who fear for both their own traditions and economic livelihood. This can have an adverse effect upon modernization as tensions may lead to the drain of educated manpower and needed capital. Where the defined opposition is a fringe group, such as the communist insurgents in Thailand, this problem is less severe. Finally, in an environment of increased religious rhetoric, radical groups within the religious community itself may gain encouragement, thereby dividing the believers themselves.

Against the predictions of secularists and modernization theorists, we can expect religion to continue to play a vital role in Third World societies. This is fueled by changing and more mobilized traditional societies seeking identity in their faiths as a refuge against the new challenges of Western technology and values. This will mean that religious practices and beliefs will, with perhaps decreasing power, remain as forces helping to determine the pace of change in both positive and negative ways. In this environment we must also expect political leaders to attempt to relate development to recognize values and thus to emphasize legitimizing elements from the traditional heritage of their people. However, it would be a serious misinterpretation of these societies to believe that this will necessarily be a hindrance to technological change. Rather, it may be the "appropriate technology", not in technical but in cultural terms.

Notes

1. I do not want to enter the philosophical argument regarding the desirability of technological change, although this issue is treated extensively in religious literature in the Third World.
2. Fred R. von der Mehden, RELIGION AND MODERNIZATION IN SOUTHEAST ASIA (Syracuse: Syracuse University Press, 1986), p. 6. This book provides many examples of such attitudes. Views towards Islam can be found in E. Said, ORIENTALISM (New York: Pantheon, 1978).
3. For quotes of these observers see von der Mehden, RELIGION AND MODERNIZATION and S. Alatas, THE MYTH OF THE LAZY NATIVE (London: Frank Cass, 1977).
4. For an excellent treatment of Protestant missionary view see K. Clymer, PROTESTANT MISSIONARIES IN THE PHILIPPINES, 1898- 1916 (Urbana: University of Illinois, 1986).
5. Among these social scientists were W. E. Rostow, POLITICS AND THE STAGES OF GROWTH Cambridge University Press, 1971), D. Lerner, PASSING OF TRADITIONAL SOCIETY (New York: Free Press, 1958), C. Black, THE DYNAMICS OF MODERNIZATION (New York: Harper & Row, 1966), and G. Almond and J. Coleman, POLITICS OF THE DEVELOPING AREAS (Princeton: Princeton University Press, 1960).
6. G. Quoted in D. Lerner, PASSING OF TRADITIONAL SOCIETY (Glencoe, Il.: Free Press, 1958), p. 257.
7. I will not discuss charges of "otherworldliness" or "irrational" behavior since these are difficult concepts to usefully operationalize and those expressing such views usually did so with a remarkable lack of precision.
8. For these sorts of data see M. Spiro, BUDDHISM AND SOCIETY: A GREAT TRADITION AND ITS BURMESE VICISSITUDES (New York: Harpers, 1970); P. Wilson: A MALAY VILLAGE IN MALAYSIA (New Haven: HRAF, 1967); K. Wells, THAI BUDDHISM: ITS RITES AND PRACTICES (Bangkok: Christian Bookstore, 1960); and S. Tambiah, WORLD CONQUEROR AND WORLD RENOUNCER (Cambridge: Cambridge University Press, 1976).
9. See, for example, J. Nguyen Van Khol, "A Study of the Impact of Christian Missionaries on Education in Thailand, 1662- 1910." Ph.D. Diss., St. Louis University, 1972.
10. There is considerable debate on these points as religious schools do not always have high prestige and, while some parents distrust the state schools, a sizable number of others question the utility of religious education for contemporary needs. See, M. Thomas, SOCIAL STRATA IN INDONESIA: A STUDY OF WEST JAVA VILLAGES (Jakarta: V. Antarkarya, 1975); K. Orr, M. Billah and B. Lazarusli, "Education for this Life or for the Life to Come," INDONESIA 23(1977); and S. Siddique, "Moulding the Muslim Mind," ASIA WEEK (March 20, 1981). For examples of how religious schools in Indonesia are used to extend development and contemporary subjects see the journal PESANTREN'S LINKAGE, sub-titled "Participation from the Bottom."
11. See J. Schechter, THE NEW FACE OF BUDDHA (New York: Coward: Mcann, 1967) and W. Klausner, "Popular Buddhism in Northeast Thailand," in

CROSS-CULTURAL UNDERSTANDING EPISTIMOLOGY IN ANTHROPOLOGY, F. Northrop and H. Livingston, Eds. (New York: Harper & Row, 1967).

12. See S. Suksamran, POLITICAL BUDDHISM IN SOUTHEAST ASIA (London: Hurst, 1977).
13. Asian Social Institute Research Department, THE CHURCH AND DEVELOPMENT IN THE PHILIPPINES (Manila: mimeo, 1975).
14. Lembaga Studi Pembangunan, LAPORAN 1981, 1982 (Jakarta, N.D.), p. 45.
15. See J. Vredenbregt, The Haddj," BIJDRAGEN TOT DE TAAL: LAND- EN VOLKENKUNDE, 118 (1962) and C. Geertz, ISLAM OBSERVED (New Haven: Yale University Press, 1968).
16. This does not necessarily mean that they support more "liberal" interpretations of Islam or political-economic issues. See J. Peacock, MALAY PURITANS: REFORMIST PSYCHOLOGY IN SOUTHEAST ASIAN ISLAM (Berkeley: University of California Press, 1978).17See Spiro, OP CIT and H. Phillips, THAI PEASANT PERSONALITY (Berkeley: University of California Press, 1965).
18. Alatas, MODERNIZATION AND SOCIAL CHANGE (Sydney: Angus and Robertson, 1972), pp. 19-20.
19. See von der Mehden, OP Cit20See Burma, PYIDAWTHA CONFERENCE (Rangoon: Minister of Information, 1952) and PYIDAWTHA (Rangoon: Economic and Social Board of New Burma, 1954).
21. Lembaga Studi Pembangunan, LAPORAN 1981, 1982 (Jakarta, nd), p. 45.
22. Statement by a leader of a religious agricultural school, quoted from KOMPAS, January 14, 1987 and presented in INDONESIA REPORT - CULTURE AND SOCIETY SUPPLEMENT, 20 (February, 1987).
23. Abdurahman Wahib, "Development by Developing Ourselves" (Jakarta: mimeo, 1980).
24. B. Effendi, "Negotiating the Future at Pesantren Pabelan," MIZAN, I (January 1984), p. 66.
25. M. Richardson, "Back to Confucius," FAR EASTERN ECONOMIC REVIEW, 115 (February 19, 1982), p. 26.
26. IBID.
27. See C. Muzaffar, ISLAMIC RESURGENCE IN MALAYSIA (Petaling Jaya: Penerbit Fajar Bakti Sd. Bhd., 1987).
28. See D. Mauzy and R. Milne, "The Mahathir Administration: Discipline through Islam," in B. Gale, Ed., READINGS IN MALAYSIAN POLITICS (Petaling Jaya: Pelanduk, 1986).
29. IBID, p. 112.

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COMPETITION, TECHNOLOGY, FREEDOM, AND THE FUTURE OF THE WORKPLACE

Jon D. Wisman

Over the past decade, the humanistic ideals of economic justice, lessened inequality, and community appear to have suffered a severe setback. We seem to be living in a period of negativism and stinginess. Our students appear especially to suffer this defeatism. They often confess a lack of hope in a better future. Although repulsed by the reigning ideal of "get yours," they feel there's nothing else to embrace.

And in the absence of high ideals, politics has been reduced to personalities, blaming foreigners, and attacking technology. What little substance there might be in current political debates typically relates to timid strategies for dealing with the consequences of irresponsbile past macro-economic mis-management.

Within this political discourse wasteland, I'd like to sound a note of optimism. I'd like to suggest that there is a little noticed movement, one which has the force of inevitability behind it, which will transform our future in a most felicitous manner. The movement is toward workplace democracy; toward a society in which workers increasingly own and control the tools and resources with which they work.

There are two forces moving us toward workplace democracy. One is the much maligned and misunderstood intensification of international competitiveness and the extraordinary advances in technology which accompany it. The second force is the unprecedented affluence which has come forth since World War II. However, to understand why these two forces are propelling us toward workplace democracy, it is necessary to take note of the major impediment both to economic progress and to progress in the further evolution of human freedom. This impediment might be called "capital-labor strife."

Capital-Labor Strife

It was, of course, Marx who provided the fullest analysis of capital-labor strife. For Marx, the very rise of capitalism entailed the separation of labor from ownership and control of the tools and resources with which they work. Peasants were forced from the land by poverty and the Enclosure movements while craftspeople were driven out of business by factories operating with wage labor. The consequence of this separation of labor from tools and resources is that the interests of workers and those who own and control the means of production are not the same.[1] Indeed, they are conflictual -- there is capital-labor strife. Although capital-labor strife has not yielded the class conflict and socialist revolution which Marx predicted, he was nonetheless correct in viewing it as the central antagonism or contradiction within capitalism, as the central impediment to further economic progress and the advance of human freedom.

Capital-Labor Strife Ignored

Although an understanding of capital-labor strife is crucial for grasping the nature of modern economic society, it has been all but ignored by mainstream economists. There are several reasons for this. The quality of work, especially the individual's control over his or her workplace, has not been granted significant importance. Second, because mainstream economics focuses almost exclusively on the workings of markets, it takes the distribution of ownership and control of the means of production as given, as beyond the purview of economic science.

A third reason why capital-labor strife has been all but ignored is that its intensity varies tremendously. Three principal forces might keep capital-labor strife latent. First, if workers are disenfranchised politically, their interests may not receive expression. A second political force holding capital-labor strife latent is the patriotism accompanying the threat (real or opportunistically "created") of external aggression. And third, because robust economic growth typically results in larger real incomes for both capitalists and workers, there is a greater chance of industrial peace.

Manifestations of Capital-Labor Strife

Although the consequences of capital-labor strife are discernable in practically all spheres of socio-economic life, they can especially be seen in such domains as the options available to firms facing foreign competition, in the costs of monitoring labor, in the issues of workplace safety, in work rules, in the political business cycle, and in international financial instability. Due to time, only the first -- the options available to firms facing intensified foreign compeition -- will be discussed.

The centrality of capital-labor strife in contemporary capitalist societies is perhaps most visible in the reactions available to a firm in the face of heightened foreign competition. Note, for instance, the options currently available to an affected firm. The quickest and most effective immediate response would be to lower wages. It would not then be necessary to reduce output and leave capital idle. Understandably, workers will resist such a strategy. After all, management is first and foremost beholden to "absentee owners", not workers. Consequently, workers suspect that wage concessions will not be in their long-term interests, but rather in the interests of those who receive the profits. A second strategy would be to speed up the work process. But workers would resist this strategy for the same reasons they resist wage cuts.

A third, more long-run strategy, would be to seek out new cost-reducing technology. However, insofar as much technology is labor-displacing, this too meets worker resistance. In fact, capital-labor strife places workers in the unenviable position of Luddites. A fourth, far more radical strategy, is for the affected firms to relocate their plants, domestically or internationally, where wages are lower, devastating the affected communities and often leaving to decay the infrastructure built to support the plants. A fifth option for dealing with foreign competition is to petition government for trade protection, subsidies, or both. Although this strategy transcends a firm's capital-labor strife by joining the two against the interests of consumers and taxpayers, it is unlikely to do more than slow and postpone the industry's decay, tying up scarce resources in an inefficient lost cause.

Toward More Democratic Property Rights

Over the past two centuries, economists such as Smith, Marx, Veblen, and most recently Douglass North, have taken note of the manner in which existing property rights inhibit technological and economic progress. Capital-labor strife is just such an instance. Fortunately, as noted above, there are two forces moving us beyond this institutional impediment to progress. The most powerful is economic in the broad sense of the term: the intensification of competition. The second has to do with where we are in the evolution of human self-determination or freedom.

Intensification of Competition

As noted earlier, when growth is robust, capital-labor strife tends to remain relatively dormant. For instance, broad-based economic growth after World War II was in substantial part due to the fact that much American industry held somewhat of a world monopoly position. Because so much of the productive capacity of other industrial powers had been shattered by the war, the U.S. enjoyed a long-run advantage. For instance, in 1950 U.S. industry produced approximately 60% of the manufactured output of all Western industrialized countries. In the early 1950s U.S. industry accounted for 29% of world exports of manufactured goods.[2] In addition, as Robert Lawrence points out, "In almost every field U.S. firms stood at their technological frontier and enjoyed the economies of scale resulting from access to a large, integrated, and extremely wealthy market."[3]

It might also be noted that a number of institutional changes had occurred which would serve to maintain relative capital-labor peace. Most notable are: the creation of a legal framework for collective bargaining; social security, unemployment insurance, disability payments, and workers' compensation.

The post-war accord between capital and labor, along with the favored position of U.S. industry meant that competitive pressures were mild, at least relative to what they were to become. Wages and employee benefits did not greatly threaten profit margins, not to mention survival."[4] However, as Europe and Japan recaptured their industrial capacity and began experiencing "economic miracles," competitive pressure on selected American industries intensified. The U.S. lost its trade surpluses, first in textiles in the late 1950s, to be followed by steel and automobiles in the mid-1960s.[5] Over the next 20 years foreign competition would increasingly intensify for essentially all U.S. industry.

Heightened competitive pressures have meant that firms must struggle ever harder to cut costs and enhance productivity. But since most costs are current labor costs, this has meant increased downward pressure on worker wages and benefits. Thus, between 1966 and 1973 "the average annual growth of real spendable hourly earnings fell to 1.0 percent."[6] And since 1973, real spendable hourly earnings have fallen by approximately 10 percent. The relative post-war capital-labor harmony has been eroding away.

Intensified competition, when accompanied with downward wage rigidity, increases risk, especially of long-run investment. Consequently, as competition intensifies, investment becomes increasingly short-run,[7] which then decreases productivity and a country's ability to compete in world markets. Since World War I this has essentially been the fate of England. But in recent years, the greater competitiveness of the world economy means that all countries must increasingly struggle to avoid England's fate. There is only one means of doing this. Capital-labor strife must be transcended. There is little likelihood that competitive pressures will abate. Indeed, such pressures can be expected to continually intensify into the foreseeable future. Consequently, the first economy that manages to overcome capital-labor strife will command a considerable competitive advantage. Indeed, it would force all others to adopt the same strategy. But the only strategy which would effectively eliminate capital-labor strife is to accord ownership and control of capital to labor itself.

The competitive superiority of a firm owned and managed by its workers can be seen in the strategies available in face of increased competitiveness from abroad. The first, quickest and most immediately effective response would be to enable a lowering of the price of the good they produce by lowering their own wages. This would allow them to continue production at full capacity so that resources would not be wasted through idleness. Since the firm is theirs, they would have no reason to fear that such a move might harm their long-term welfare by, for instance, reducing their future wage-bargaining position. Meanwhile, they could go about doing what is necessary to improve efficiency and thus their competitive position. There would be no reason to resist labor-saving technology (e.g., robotics), since their jobs are secure so long as the firm remains viable.

Workers would not, of course, have any incentive to relocate their plants in other parts of their country, much less in other countries. The principal current incentive for plant relocation -- finding cheaper workers -- would no longer exist.

What would perhaps constitute the most exciting economic benefit of worker ownership and control would be the resulting technological dynamism. In current American firms, where decisions come from the top down, very few people have a direct, professional, interest in technological progress. Indeed, those at the top may keep technological knowledge secret from workers for fear that they may react negatively or take the knowledge to a competitor. In a worker-owned and managed firm, by contrast, everyone not only possesses a strong interest in technology, but it is to each worker-owner's advantage that everyone else in the firm know as much as possible. There need be no reluctance to sharing knowledge with another worker out of fear that in hard times such sharing might mean that the other keeps his job but you lose yours. Indeed, the social environment of the workplace would encourage life- long learning by the entire labor force. The benefits to the U.S. economy would be clear: The energies of not just a few specialists, but rather of the entire work force, would be elicited in the struggle to maintain our technological leadership.

The Progression of Human Freedom

The history of the human species is the history of increasing freedom. This is not meant as a teleological assertion. There is no necessity to freedom. Rather, it is merely a consequence of the unique evolutionary path of the human species. This freedom is founded upon humanity's increasing control over the material environment. The upward trend, although not without interruptions and even reversals, has been geometric. And since World War II something unprecedented in human history has occurred: in the U.S., and parts of Europe, generations have come of age where the overwhelming majority live without any real sense that material privation might be their lot.

To recognize how extraordinary this is, we need only reflect upon the fact that throughout history work was compelled by extreme material privation. However, in recent times, as productive capacity began to outpace population growth, the scarcity-imposed work ethic weakened. It came to be replaced in part by a democratization of what Veblen referred to as conspicuous consumption. People would work hard, even at boring and stultifying jobs, so as to participate in competitive consumption. However, this consumption compulsion to work seems to work well only when combined with a degree of actual material insecurity. Hence, when that first post-World-War II generation, raised in such unprecedented affluence, entered the job market in the mid-sixties, they exhibited a degree of reluctance to work hard merely for income with which to buy luxury consumer goods. A labor-discipline problem appeared, which, it has been suggested, may be a root cause of the productivity slowdown which begins after 1966.[8] This would suggest that the very breakdown in the relative post-World-War II capital-labor peace may have been due, at least in part, to the unparalleled extent to which this new generation was freed from fear of dire material privation.

Although this trend has been interrupted by the decline in worker real incomes since 1973, there is every reason to expect that this setback is temporary. As workers are increasingly distanced from the threat of dire economic privation, they will continue to demand more freedom in other domains of their lives. And the domain in which the majority of humans in modern society possess the least freedom is the workplace. The vertical structure of authority within the workplace is an affront to human dignity; it means that otherwise free humans must take orders unquestioninglly from above; they are bossed about. At some point workers will no longer be willing to sacrifice a substantial portion of their freedom for merely more consumer luxuries.

Hastening the Inevitable

Although workplace democracy appears inevitable, if left to the anarchy of the market system, the pace of evolution is likely to be slow. But because a substantial portion of the benefits of workplace democracy are public goods, it should be much more actively encouraged by government.

Advocacy of more government programs is, of course, currently out of political fashion. Nevertheless, it is possible to imagine measures which could be taken which would neither lead to excessive intervention nor result in large new bureaucracies. For instance, in addition to tax incentives, government might offer a comprehensive program of loan guarantees to workers for the purchase of their plants. If such a program were carefully crafted, it need not involve more than a nominal increase in government spending. Indeed, an end to capital-labor strife might well lead to a long-run decrease in the size of government. In any event, the bipartisan backing which created the ESOP plans suggests that programs to bring about workplace democracy should find broad-based political support. What could be more traditionally American than the greater self-reliance, self-determination, and freedom which an economy of worker self-management promises?

Notes

1. The term "interests" is explicitly used here in lieu of "classes" due to the fact that the interests of capital and labor are not so neatly divided between captitalists and workers.
2. Robert Z. Lawrence, "Is Trade Deindustrializing America? A Medium-Term Perspective," Brookings Papers on Economic Activity, I, 1983, p. 145.
3. Lawrence, p. 145.
4. Thus, between 1948 and 1966, "Real spendable hourly earnings increased at an average annual rate of 2.1 percent. Thomas E. Weisskopf, Samuel Bowles, and David M. Gordon, "Hearts and Minds: A Social Model of U.S. Productivity Growth," Brookings Papers on Economic Activity, I, 1983, p. 385.
5. Lawrence, p. 146.
6. Weisskopf, et. al., p. 385.
7. Increasingly investment takes the form of financial speculation in existing assets as opposed to the creation of new productive capital. Weisskopf, Bowles, and Gordon report that "Increases in financial assets, as a percentage of all corporate uses of funds, rose from an annual average of 19.8 percent in 1959-66 to 25.4 percent in 1966-73 and to 25.8 percent in 1973-79." Weisskopf, et. al., p. 389. Of all long- run private investment, spending declined most dramatically for the category which has the longest gestation period -- research and development. This can be seen in the following fall in average annual growth rates for patent applications filed for new inventions over successive five-year periods: 1956-60 to 1961-65, 2,5 percent; 1961-65 to 1966-70, 1.8 percent; 1966-70 to 1971-75, 1.4 percent; and 1971-75 to 1976-80, - 0.1 percent. Weisskopf, et. al., p. 389.
8. Weisskopf, et. al. attempt to empirically demonstrate this relationship.

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A MEDITATION ON ECONOMY AND SOCIETY

Mark A. Lutz

Introduction

It is generally agreed that economic science since Adam Smith has been a powerful agent for modernization and commercialization of society. As a result, it should come as no surprise that many critics of modern society have shown considerable interest in constructing an "alternative economics", an enterprise that has, however, been largely ignored by professional economists in academia. Given the diversity among "anti-economists" it would be too simplistic to assume that such conspiracy of silence is based only on vested interest and therefore unjustified. To the contrary, there are many pitfalls to a meaningful critique and a powerful reconstruction of modern economics. Among the many problems and misperceptions, let us here point to three.

First, economics should not be made a scapegoat for all social ills. To a very large extent the crisis of economics merely reflects a crisis in modern civilization.

Second, modern economics cannot be rejected wholesale. To the extent that it seeks to merely describe and explain observed economic activity there is nothing wrong with it. The problem only enters when economics pretends to offer a valuable scientific framework for prescription of social policy.

Third, there is a tendency for alternative economists to sermonize, to condemn consumerism and excessive materialism by preaching 'better' values of voluntary simplicity, ecological responsibility, etc. In doing so, they tend to neglect the effect of social structures and forces on individual conduct and never ask the question why people are addicted to TV and shopping centers.

More generally, a 'living economy' needs to be seen as an organic interrelation and dynamic interaction between individuals, technology, economics and society. Given such a complex and intertwined matrix, it may be impossible to change any particular part (e.g. economics) without simultaneously also working on the whole. In what follows, we attempt to indicate one way along which a holistic alternative economics could perhaps more meaningfully proceed.

The Problem: An Impersonal Force

Let us posit that there exists some powerful, alien Force that seems so often to effectively frustrate the realization or well-intended ideas and social ideals like, for example, greater local self-sufficiency in food production, establishment of viable cooperatives, etc.

We believe the source of this Force is the quest for individual gratification. It is satisfied by either political power (i.e. the ability to gratify our desire without direct consent of others) or by economic power (i.e. the accumulation of wealth allowing us to directly purchase the consent of others for the purpose of our own gratification). In the economic sphere, the driving element of the Force is the competitive spirit, particularly the profit motive.

Social legitimization of this Force is generously provided by economic science acting like a church preaching the worldly gospel of how individual self-regarding action ends up producing the common good. Students learn early to pay homage to Adam Smith's hidden yet so provident 'invisible hand'.

The Force is latent in everybody. It actualizes itself in our behaviour as soon as we seek to use others or our environment for our own purposes; that is, whenever we act like Rational Economic Man maximizing an 'objective function' defined in a commodity space. The great social philosopher Martin Buber called this type of subject/object relation the 'I-IT relation'. He warned that it was a vitally necessary attitude for securing survival, but that for a more fully human existence it had to be complemented by an unmediated and spontaneous I-THOU relation. Otherwise, in attempting to reduce all human behavior to the confines of the I-IT mode, we end up taking a mere part and pretend that it is the whole. Such a pretense must be seen as essentially evil, if by 'evil' (or 'Satan') we understand a situation where a part parades as the whole.

Finally, the Force has the interesting characteristics of being self-directing, quasi autonomous, in control of itself. Martin Buber calls this a "depotism of the proliferating IT" manifesting itself, among other things, in run-away technology.

> ... "the state is no longer led: the stokers still pile up the coal, but the leaders merely seem to rule the racing engines. And in this instance you can hear how the machinery of the economy is beginning to hum in an unwonted manner; the overseers give you a superior smile, but death lurks in their eyes. They tell you that they have adjusted the apparatus to modern conditions; but you notice that henceforth they can only adjust themselves to the apparatus, as long as that permits it. Their spokesmen instruct you that the economy is taking over the heritage of the state; you know that there is nothing to be inherited but the depotism of the proliferating it, under which the I, more and more impotent, is still dreaming that it is in command." (Buber, p. 97)

For another illustration of the autonomous character of the Force, consider the movement of internationalized capital. Six years ago, in a speech on October 1, former Mexican President Lopez Portillo testified before the United Nations:

> "We have been a living example of what occurs when that enormous, volatile, and speculative mass of capital goes all over the world in search of high interest rates, tax havens, and supposed political and exchange stability. It decapitalizes entire countries and leaves destruction in its wake."

Surely, enough has been said to indicate the nature and danger of this impersonal Force, to suggest that effective proposals for its curtailment are bound to constitute the very foundation for a meaningful and holistic new 'Living Economy' or, perhaps better, Human Economy.

The Solution: Integrating the Force

Since the Force is rooted in a dualistic human nature, more specifically in the basic human attitude of I-IT with man's will to profit and power, both detached from the will to enter into authentic human relationships, it cannot be simply uprooted or otherwise destroyed. Instead, it needs to be (re)integrated in the life of an active and genuine community able to control and guide it for the purpose of the common good.

A truly human economy has to suggest an institutional framework that will no longer encourage the disintegration of the social fabric and communal life. The first step in this direction is the realization of effective social control over economic activity, a step that ensures above all a correspondence between the economic domain of the market and the socio-political domain of administration. It implies a socially directed market economy, not a system based on economic laissez-faire . It implies community control of enterprise rather than absentee ownership of land and capital. The latter point suggests the intrinsic incompatibility of the modern corporation with human economy. Instead, factory production will have to be carried out within a framework of community ownership and employee self-management.* Finally, and perhaps most importantly, it implies an end to so-called "free trade" in a global economy devoid of an effective global government. What is called for instead is social control of trade and capital flows, or what University of Wisconsin Professor John M. Culbertson (1984) calls 'managed trade' based on bilateral trade agreements particularly with the newly industrializing countries in Southeast Asia. Otherwise, standard lowering international competition will render any meaningful human welfare and environment-oriented regulation, as well as the goal of viable worker cooperatives, largely utopian.

Conclusion

If there is to be a comprehensive and meaningful new 'Living Economy', an economics we can live with, it will be grounded more in social philosophy than in traditional social science. Moreover, it will have its roots in philosophical anthropology exploring the question of what is essential human nature rather than in a scientific anthropology inclined towards a nihilistic cultural relativism.

Similarly, such a new Human Economy seriously questions the repeated pleas coming from some corners of alternative economics that call for individual "empowerment" often based on some mystical idea of mind over matter. Rather, true human empowerment comes from social and political action within an enabling institutional framework. In this way, the real power will emanate from genuine cooperation of man with man, from brothers and sisters realizing their common humanity in self-governed, democratic and participatory social administration.

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* For details on these policies, see Lutz-Lux (1988), especially chapters 8 and 12.

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NUCLEAR POWER AND TECHNOLOGICAL AUTHORITARIANISM

John Byrne and Steven M. Hoffman

Nuclear Society and Technological Progress

When the lid blew off the Chernobyl No. 4 nuclear reactor on April 26, 1986, it released the largest quantity of radioactive material ever in one technological accident. The estimated 28 megacuries of escaping gases dwarfed the less than one megacurie released in the 1957 Windscale (U.K.) accident and the 17 curies from the 1979 Three Mile Island (U.S.) accident. One hundred thirty-thousand people within a 30 kilometer radius were evacuated, and 300-400 million people in 15 nations were put at risk of radiation exposure. Present forecasts of additional cancer deaths attributable to the Chernobyl accident range from 5,000 to 75,000 (Byrne and Rich, 1987: 4).

The Chernobyl explosion is the latest in a long series of technological "incidents" marking this era's commitment to what Alvin Weinberg has called a "magical energy source" (Weinberg, 1972: 33). Two workers died in accidents at the Los Alamos plutonium processing plant in 1945-46; a partial core meltdown occurred in 1952 at Canada's experimental Chalk River plant; the 1957 fire at Britain's Windscale plant contributed to making the Irish Sea the most radioactive body of water on the face of the earth; an explosion in 1961 at an experimental nuclear reactor facility in Idaho Falls, Idaho killed three operators; in 1966, the Fermi demonstration breeder reactor near Detroit experienced a partial core meltdown; a Soviet breeder reactor accident in 1973 took an unknown toll in human lives; an electrical cable fire in 1975 at the Browns Ferry, Alabama plant crippled the emergency core cooling system; the accident that couldn't happen did at Three Mile island in 1979; in 1984 a major accident was only narrowly averted at the La Bugey reactors in France; the Davis-Besse plant (Toledo, Ohio) in 1985 nearly repeated the TMI accident; and the Superphenix fast breeder reactor (Tricaste, France) was closed in early 1986 after radioactive gases were released and an unexplained leakage of 25 tons of a highly volatile coolant was discovered.

Recently, the nuclear industry has been plagued by severe financial problems. The French nuclear authority, the Electricite de France (EDF), has ordered "more plants than the country needs or can afford. EDF now has a debt of $32 billion -- exceeding that of most developing countries" (Flavin, 1987: 56). In the United States, a nuclear power project precipitated the largest default in the history of the municipal bond market when the Washington Public Power Supply System (WPPSS) declared its inability to honor financial obligations for $2.1 billion worth in bonds issued to finance two nuclear power plants. An additional $6.7 billion in principal and $23.8 billion in interest is still outstanding on these and three other WPPSS nuclear plants (Byrne and Hoffman, 1986). The promise of lower operating costs for nuclear power plants has not materialized according to a recent study by the Tennessee Valley Authority, the nation's second largest nuclear utility (1985: 5). Between 1970 and 1986, operating and maintenance costs for nuclear plants increased fourfold in real dollars, or 11.4 percent per year above the rate of inflation (Energy Systems Research Group, 1987:3). From 1981 to 1985 operating, maintenance and fuel costs increased 50 percent for nuclear plants compared to 10 percent for coal plants (NARUC Bulletin, 1987: 14-15).

There has been a tendency by some writers to point to the numerous accidents, disasters and financial problems as evidence of the nonviability of nuclear technology (Flavin, 1987; Stobaugh and Yergin, 1983; Komanoff, 1984 and 1981). In response, defenders of nuclear power have cited variously the accidents and death tolls on American highways, the radioactivity of coffee, and other risks of ordinary life, and conclude that elimination of the highway system and coffee drinking would be as rational as banning the use of nuclear power. Both positions seek to analyze the technology in its future tense, namely, its suitableness as a source of energy in the coming years apart from its past or present institutional context. Yet, it is precisely that context which explains how nuclear technology got to where it is. An understanding of the institutional underpinnings of nuclear power is essential to an analysis of its prospects. While plant closings, order cancellations, and financial boondoggles have recently become common phenomena in the Nuclear Project, its viability does not seem to have been damaged significantly. *After* Chernobyl, 118 nuclear plant construction orders remain for start-up by 1990 (Ramberg, 1986: 318).

The Characterology of Nuclear Necessity

Nuclear power is the unique possession of technological civilization. It represents a high-point in technical and scientific achievement. Through the Nuclear Project, the disparate scientific, intellectual, military and industrial communities have been melded into a single instrumentality to foster technological progress.

Following Jacques Ellul's advice that "we must assess, not the internal characteristics of the technique, but the actual situation of technique in human society" (1964: 64), we offer in this section an analysis of the social necessity of nuclear technology in the modern era. It is our position that there are compulsive forces operating in technological societies which make nuclear power development virtually unavoidable. While recognizing these deterministic elements, we do not believe that nuclear power development is beyond challenge. However, in our view for resistance efforts to be successful, the relation between technique and human society must be altered. We do not claim to know how this is to be done. But we hope that the analysis provided here can usefully serve, along with the significant contributions of other writers, to clarify the nature of the challenge.

The idea of nuclear power did not surface in response to pressing social need. There was no economic demand in 1946 for this "energy source" when the U.S. launched its research program. An energy shortage was not imminent. There had been no technical failure or breakdown in the energy system that required a new energy technique. In the face of a labor surplus after World War II, there was little need for a technology which would allow energy to be substituted for labor in the production system. In fact, suspicion and even resistance from utility owners and liability insurers was encountered during the initial stages of this technology's promotion. Nuclear power developed not to solve energy problems but because it was a necessary step in the progress of technology.

J. Robert Oppenheimer recognized in 1949 that the development of the nuclear technique had the status of an imperative for technological society: "When I saw how to do it, it was clear to me that one had to at least make the thing. The [hydrogen bomb] program . . . was technically so sweet that you could not argue about that" (quoted in Winner, 1977: 73). No social or economic criterion, only technical "sweetness" was necessary to justify the Nuclear Project.

The development of nuclear power occurred and continues to occur because: (1) it is technically logical within the existing ensemble of technique; (2) it advances a pattern of technical universalism; and (3) it contributes to an aesthetic of technique, a "best way" to appreciate the pure possibility of technological civilization. Together these characteristics represent a self-rationalizing institutional context for the development of the nuclear technique.

Technical Possibility and the Irrevocability of Technical Knowledge

At any moment, only some things are technically possible. Technical options depend for their development, at least in part, upon already existing techniques and ideas. Each advance in technology represents both an addition to the infrastructure of science, industry and government for solving technical problems, and a tool to confront the next generation of barriers. While technical understanding at any the moment cannot embody perfect foresight of problems-to-come, an heredity principle can be observed in the evolution of technology. This heredity principle both reflects and motivates new techniques in a manner akin to paradigm as described by Kuhn in his analysis of normal science (Kuhn, 1970). Conflicting ideas and techniques are not precluded by the operations of this principle; hypothetically, different, even contradictory, approaches can exist. But they are almost always practically unworkable because they lack a clear place in the technological chain. An uninherited approach is constantly under threat of self-contradiction – of what value is a means that cannot easily and readily be used?

The technical possibility of nuclear power was an inherited one. Knowledge of how to control a nuclear reaction and utilize the heat energy given by it evolved from scientific understanding of the possibility of an atomic chain reaction. Once this understanding was established, decisions hinged upon intrinsically technical matters. Although two options could be identified, namely, setting off a chain reaction or controlling a continuous one, from a technical point of view the developmental sequence and direction was predetermined. Given the state of scientific and technical knowledge and the institutional organization of Western research and engineering on the eve of World War II, the first option involved much simpler technical problems and logically preceded the second. Control methods necessary for bomb-making could be quickly attained, while control methods for nuclear-based electrical and heat generation were more complex and took longer to fashion. In this socio-technical sense, the atomic bomb heralded the nuclear plant: "Could not atomic engines and atomic power have been discovered without creating the bomb? . . . If atomic research is encouraged, it is obligatory to pass through the stages of the atomic bomb; the bomb represents by far the simplest utilization of atomic energy" (Ellul, 1964: 98-99). As Joseph Camilleri points out, even societies which attempted "peaceful" nuclear development were unavoidably incorporated into the military project (1984: 8).

> [A] few small European nations anxious to capitalize on indigenous technology or independent access to uranium and heavy water – notably Norway, Sweden, Belgium and the Netherlands – were able to initiate a modest programme of nuclear research and development unrelated to any military objective. But even here the countries in question were dependent, at least in part, on access to fuels and technology which only the existing or aspiring nuclear weapons states could supply.

Finally, Oppenheimer observed that "the close technical parallelism and interrelation of the peaceful and military applications of atomic energy "precluded their separate development" (1955: 9).

Once this knowledge had proceeded to the point where it was only a "matter of time" before it could be used, the development of the nuclear technique was assured; its technical possibility had been realized. Stopping or reversing technological development at this point would have required erasure of the corresponding technical knowledge. For technological (or any) society, this is impossible; indeed it is unthinkable. While particular aspects of technical knowledge can become obsolete with the arrival of new ideas and methods, there is no meaning to the notion of returning society to a pre-existing state of knowledge. The heredity principle precludes going backward: each assembly of ideas includes earlier vintages of knowledge which enable thinking to move forward, to progress. The necessity of earlier ideas can be removed with technical advances, but technical advances cannot be reversed and can only be removed by *subsequent* innovations of ideas and means. In this sense, technological knowledge is irrevocable.

Yet, implementing a technical possibility very often raises issues of compatibility with existing technique. For nuclear power, there were few obstacles presented by the operating energy system. Tendencies toward centralized production and economic concentration have been in evidence in the electric supply system since at least the beginning of this century. When pressure-staging turbines were introduced in the 1880s, generating capacities averaged 7.5 kW. By 1930, the capacity of U.S. generating units had increased to 200,000 kW and by 1955, it was possible to build 1,000 MWe plants (Messing, et al., 1979: 3). Alongside the escalation of powerplant size, there was a pronounced trend toward increasing organizational scale as the utility industry underwent a process of merger and consolidation. Between 1900 and 1920, the number of investor-owned utilities in the U.S. grew from 2,800 to 6,500 to serve a rapidly expanding electricity market. Over the next twenty years, supply was "rationalized" and spatial monopolies created to maximize opportunities for selling large blocks of power produced by the new machines. The number of private utilities fell to under 1,000 as holding company pyramids were formed to link regional supply operations. By 1955, there were approximately 500 private companies controlling 80 percent of national sales. Since then, the number of companies has been halved while the percentage of total sales controlled by these companies has remained approximately the same (Messing, et al., 1979: 45-56; Hughes, 1983: 201-226 and 391-394).

Together these technical and economic orientations toward the supply of power represent, to use Ellul's term, an "ensemble of technique" – a common effort of capital, machinery, production methods, research and consumption in support of the best way of manufacturing and distributing electrical energy (Ellul, 1964: 90). This common effort fuses the worlds of the engineer and the economist: coordination, integration, control, order and system, the icons of engineering, are harmonized with efficiency, rationality, optimality and equilibrium, the canons of economics. From such an attuned world emerged a vertically and horizontally integrated "network of power" (Hughes, 1983). Only an integrated network could satisfy the requirements for large regional markets and therewith create the conditions for predictable demand. However, the thermal efficiencies and scale economies of centralized, linked power systems could only be realized with the assurance of reliable market demand; efficiencies and economies are the outcomes, rather than the causes, of an ensemble of technique. Without the integrated network, there could be no regional market and no justification for the development of large power plants.

The demands of the electrical ensemble of technique were (and are) centralized production, integrated operations and planning, and regionalized transmission networks and power pools. Nuclear power had no difficulty complying with these objectives. Indeed, this technology intensified electrical progress in the form of increases, often by several orders of magnitude, in steam pressure, boiler and turbine capacities and thermal efficiencies. But perhaps its most significant achievement was in megawattage. With government and utility commitment to nuclear power, growth in the scale of generating capacity entered an unparalleled stage in the history of electrical production. For a time, 3,000 MWe plants were contemplated by the U.S. nuclear industry, before a ceiling of 1,300 MWe was settled upon. As Messing et al. point out, the single-minded pursuit of large plants virtually eliminated commercial interest in and research on small- and medium-scale facilities (1979: 7-8). Nuclear power promised not only to accommodate the demands of prevailing technique, but to augment them.

This technology inaugurated a new "planning reality" for the utility industry which sought redefinition of political authorities between national and local governments, and in some cases, between two or more national governments in an effort to make room for nuclear power (Messing et al., 1979: 14-16). Grid interconnections, wheeling techniques and new transmission line technology (with carrying capacities of up to 765 kV) assumed prominent roles in industry thinking and have become adjuncts of the new reality stimulated by nuclear power. In this respect, whatever the extent of its eventual use, nuclear power has already so affected the technical environment as to constitute a new root for reticulating electrical technique. Specifically, the next generation of power technology will have to respond to the nuclear inheritance as a functional component of the electrical ensemble.

Nuclear Power and Technical Universalism

Nuclear power is grounded in and contributes to the universalism of technique in at least two ways. First, it fosters the spread of the technical orientation as a geographic phenomenon. And second, its development represents a key step in the integration of the dominant social institutions in technological society.

As Hughes points out, the electrical ensemble historically served to help universalize the geographical preeminence of technique. In his study of Germany, Great Britain and the United States during 1880-1930, a common technological history is adduced (Hughes, 1983: 405):

> The similarities can be . . . explained by the existence of an international pool of technology from which the industrial nations drew. Manufacturers engaged in international trade, patents were generally

> licensed for international use, scientific and technological literature circulated to all of the world's centers of learning, courses in engineering schools described and rationalized world experience in electrical technology, and engineers and inventors moved and consulted easily across national boundaries. Technology transfer was not so much from point to point or place to place as from place to pool to place.

This raises a question, though, as to whether the geography of technique is determined by the plasticity of technical means to fit social aims, or the plasticity of social institutions and aims to fit technical requirements. Hughes is persuaded by the variety he finds in "regional cultures" of technical systems that it is technique, rather than society, which bends: "The common technology of the [international] pool was shaped to suit the place" (1983: 405). However, he implies that this relation may have changed contemporarily as emphasis is placed upon "a superior, advanced technology -- 'the one best way' -- a way that transcends regional and national differences" (1983: 405). Even in the period of his study, though, he points out that cultural factors faded in importance when confronted with issues of technological progress. In the early part of the 20th century, Hugo Stinnes, chairman of the Rheinisch-Westfalisches Elektrizitatswerk AG, and Samuel Insull, chairman of Commonwealth Edison Company, adopted identical strategies to mass produce and market electricity and to "rationalize" utility operations and planning, notwithstanding the existence of significance regional differences (Hughes, 1983: 404-412).

In his development of the concept of technical universalism, Ellul argues that it is society which adapts and accommodates to technical advance, or as he terms it, "technical invasion" (1964: 116-133). Nontechnical culture "collapses" in the face of technical culture because technique is both indispensable and totalitarian. While each culture contains within it the essential technical means for achieving its existing goals, Ellul points out that the logic of technical possibility drives the culture to innovate beyond its present requirements. The instrumentality of technique becomes valued in and for itself, and eventually all aspects of social organization are subjected to the scrutiny of technical consideration: "Technique can leave nothing untouched in a civilization. Everything is its concern . . . [I]t is a whole civilization in itself" (Ellul, 1964: 125-126). The geography of technique displays the universal nature of technical advance: "Until now it was generally accepted that very similar social environments were necessary if propagation of techniques was to occur. This is no longer true. Today technique imposes itself, whatever the environment" (Ellul, 1964: 118).

In the case of nuclear energy systems, there are observable national and regional differences (e.g., between the systems of the U.S. and France), but these seem to be minor in comparison with the similarities. Nuclear power was delivered to societies as diverse as the Soviet Union, France, Great Britain and the United States via a "military transfer" and in each, the military and the state continue to play central roles in the articulation of this technology's development. The collaboration of science and the state was essential in all of these societies as was (and is) the organization of this collaboration outside the normal channels of government and industry. Much as with the earlier development of steam turbine technology, the spread of nuclear power has been dependent upon an international pool of technology and expertise, a research and educational infrastructure devoted to sharing information, findings and innovations (and beliefs) across national boundaries, a series of treaty agreements to aid promotion and regulation of this technology, and an oversight body -- the International Atomic Energy Association (IAEA) – to facilitate communications, standardization of the technology, and the adoption of procedures to increase plant safety.

Beyond its geographic proliferation, nuclear power serves the interest of technical universalism as a centerpiece for the institutional integration of the science, military, industry and state sectors. Camilleri depicts this integration as follows (1984: 5):

> The principal actors [of the American nuclear programme] were the armed services, private industry and finance, the legislative and executive organs of government, intelligence organisations and to a lesser extent the emerging atomic bureaucracy, sections of the scientific and technological community and even elements of the trade union movement. That is not to say that the constituents of the military-industrial complex were of one mind or always acted in unison. On the contrary, on many issues relating to the scope of the nuclear programme, the level of resource allocation, the degree and form of secrecy to be observed, the organisational arrangements to be enacted, the relationship to be maintained between the military and civil spheres of government, there were deep divisions and prolonged battles. On the other hand, it is also true to say that these groupings recognised one another as legitimate participants in the nuclear project and as sharing a common set of basic assumptions about its value and functions.

Camilleri documents a similar institutional congealing in Britain, France and West Germany. And socialist equivalents are found in the Soviet and Chinese development of nuclear power. This congealing is made possible in part because the relevant institutions in each society can communicate by means of a universal language.

Its conformity with and capacity to contribute to geographical and institutional tendencies toward technical universalism make nuclear power development a necessary step for technological civilization. It provides the means of technicizing the inorganic world of the atom and permits a shift in technical attention to the investigation of the sub-atomic sphere and to the technicization of the the organic ("death, procreation, birth and habitat") (Ellul, 1964: 128). Understood in these terms, nuclear power can hardly be rationalized as either a machine to substitute for human labor or a solution to an energy problem.

Modern Progress and the Nuclear Dream

The necessity of nuclear power derives not only from materialist characteristics of technical heredity, compatibility and universality but, in addition, from its importance to the aesthetic of technique. As Winner has argued, the appreciation of technique is not limited to a "cult of efficiency" or an "enthusiastic group of technophiles" (Winner, 1977: 277); nor is it confined to ideological purposes of justification, legitimation or rationalization. Through the technical aesthetic, societies learn the majesty of technological power, order and civilization (Mumford, 1934: 334):

> [P]ass through the waterfront of Hamburg, say, and review the line of gigantic steel birds with spread legs that preside over the filling and emptying of the vessels in the basin: that span of legs, that long

> neck, the play of movement in this vast mechanism, the peculiar pleasure derived from the apparent lightness combined with enormous strength in its working, never existed on this scale in any other environment: compared to these cranes the pyramids of Egypt belong to the order of mud-pies.

Imbued with the majesty of technological power, the technological personality realizes that a synchrony exists between material and spiritual progress. This realization has the status of undisputed belief and evidence for it is found everywhere. The technical esthete counterposes the life of misery, hunger, disease and despair of the "pre-technological" era to the present life of abundance, leisure, comfort and freedom. Langdon Winner depicts the belief as follows (1977: 102):

> Certain technical means stand at the very basis of human survival. Failure to provide for them is to invite discomfort, suffering, or even death . . .Any attempt to deny this . . .can only be an expression of malice, stupidity or madness.

From this perspective, as Winner notes, technique represents far more than a functional requirement; "it is also a moral standard, a way of distinguishing the good from the bad, the rational from the irrational, the sane from the insane" (1977: 102). The clearest (and most dangerous) implication of the aesthetic, in this regard, is that civilizations can be distinguished as "advanced" or "backwards" depending upon their technological possessions and commitments.

In this regard, nuclear power has become the preeminent symbol of advanced civilization in this era. At the September 24, 1986, meeting of the International Atomic Energy Agency *after* the Chernobyl disaster, the head of the Soviet delegation declared: "The exploitation of the atom's energy has become a realistic requirement, and is preconditioned by interests of human civilization progress." Chancellor Helmut Kohl delivered a similar message to West Germany's citizens: "Abandoning nuclear power could spell the end of the Federal Republic as an industrialized nation." And Great Britain's Energy Secretary Peter Walker concluded: "if we care about the standard of living of generations yet to come, we must meet the challenge of the nuclear age and not retreat into the irresponsible course of leaving our children and grandchildren a world in deep and probably irreversible decline" (all quotes in Flavin, 1987: 62). Finally, three weeks after Chernobyl, Soviet General Secretary Mikhail Gorbachev assessed the international importance of nuclear power for social progress: "The future of the world economy can hardly be imagined without the development of nuclear power . . .[H]umankind derives a considerable benefit from atoms for peace" (Vital Speeches of the Day, 1986: 516).

The commitment to nuclear modernism is not limited to the West. Many countries of the South have either developed substantial nuclear programs or taken steps to integrate nuclear technology into their electrical networks. This commitment has not been shaken by the Chernobyl explosion. In August 1987, Egypt's electricity minister stated that "Egypt needs nuclear generation to meet the demands for power;" an opinion shared by Cuba's Executive Director of its Atomic Energy Commission, who has committed the country to a nuclear project capable of generating 25 percent of the nation's electric needs by the year 2000. Indonesia is planning construction of two nuclear units in the 1,000 MWe range by 1999. August 1987 also saw a ground laying ceremony for the Quangdong nuclear facility in the People's Republic of China, and Taiwan, with six generating plants, envisions the need for ten new plants to supply 12,600-16,600 MWe of additional generating capacity by the year 2000. India has announced a goal of 10,000 MWe of new nuclear capacity by the same year. According to the Minister of State for Atomic Energy, the main impediment to this effort will be money; "There are no technical obstacles." Brazil and Argentina have agreed to explore joint development of a breeder reactor which would close the technology loop in their nuclear systems. Finally, the recently retired president of South Korea chose the dedication ceremony of the nation's fifth nuclear power plant as the occasion to address his country's political crisis (*Nuclear News*, 1986 and 1987).

While opposition movements to nuclear power (plants and bombs) have grown over the past twenty years and in some countries represent potent political forces, worldwide appreciation of the nuclear dream has been steady. The promise that this technology will deliver an endless source of power, a comprehensive knowledge of the underlying order of all matter, and global security based on limitless material abundance has captured the soul of technological societies. William Laurence, one of the early American nuclear propagandists, communicated why a sense of enthrallment accompanies this technological vision. In the nuclear dream, technology delivers "wealth and leisure and spiritual satisfaction in such abundance as to eliminate forever any reason for one nation to covet the wealth of another" (1959: 240), and can be compared to a "veritable Prometheus bringing to man a new form of Olympic fire" (1940: 12-13). Indeed, nuclear advocacy has frequently presented nuclear power as analogous to the discovery of fire. In his 1914 novel, *The World Set Free*, H. G. Wells has Professor Rufus summarize the modern situation (1914: 24-25):

> We stand today towards radioactivity exactly as our ancestor stood towards fire before he had learned to make it . . .just when it is becoming apparent that our ever-increasing needs cannot be borne indefinitely by our present sources of energy, we discover suddenly the possibility of an entirely new civilisation.

Alvin Weinberg continues this tradition in our time characterizing nuclear power as a "marvelous new kind of fire," and declaring that civilization finds "an inexhaustible source of energy" in "the catalytic nuclear burner" (1972: 28 and 33). Whether and in what technical forms nuclear power will be further harnessed is, in a basic sense, irrelevant. Henceforth, any generation of technique will be measured against the nuclear aesthetic and its promise of a culture of abundance (Byrne and Rich, 1986: 141-159).

The Future Tense of Nuclear Power

If the above analysis is correct, the evaluation of nuclear power's future cannot be conducted apart from the institutional context of technological civilization. Within that context, nuclear power is a necessary development. Through this technology, cooperation among the military, state, scientific and economic sectors has been facilitated and a social form has emerged in which technical, political, economic and aesthetic aspects have melded to constitute a single, integrated reality.

The future of nuclear power will be determined by the extent to which conditions for expansion of this technological orientation in societies are realized or effectively resisted. So far, there is little evidence of sustained social resistance.

Rather than challenging the values and commitments of technological societies, the Chernobyl explosion has become a focal point for identifying new political, economic and ideological measures needed to ensure the spread of the technological grid. Diagnoses by the socio-technical mainstream generally have reflected and reinforced institutional tendencies already firmly resident in technological culture. Chernobyl has been (and will likely continue to be) analyzed as an instance of human-political failure which can be avoided in the future by the infusion of greater technical discipline, order and organization into the social structure. For the technically minded, the Nuclear Project is not jeopardized by accidents such as Chernobyl since machine failure can usually be traced to human mistake, political interference, or both. Machine operation and function is still largely governed by humans either as machine designers or as handlers and users, but the hope for the future is that the role and significance of the "human element" can be reduced. The ground for such optimism is found in the belief that technological improvement is achieved by the application of logical, objective laws which are impervious to human error and political interest. Indeed, science has become the essential instrument for detecting human-political failures. From a scientific standpoint, the sensible solution to accidents in technical systems is a diminished human-political presence and activism, a greater reliance on machine autonomy (with automatic shutdown and safeguard routines incorporated into systems), and steady social investment in technical innovation. In the case of nuclear power systems, solutions take the form of "inherently safe" reactor designs, increased emergency system redundancy, more and better machines to monitor machine behavior and to serve as back-ups in the event of malfunction, upgraded technical credentials and training of system personnel, the substitution of technical reviews for political oversight, and bigger nuclear R&D budgets (Weinberg, et al., 1985).

Alongside efforts to depoliticize the technology have been and will be actions to assemble cultural support for nuclear power as an imperative of progress. This ideological tendency is rooted in the equation, commonly made in technological societies, that associates the quantity of energy produced and used with the advance of civilization (Basalla, 1980; Kash and Rycroft, 1985). However, an event such as the Chernobyl explosion and the resulting radioactive plume are a frightening reminder of the threat to all of human existence posed by the possession of the atomic secret. In the wake of this and other "accidents," it is not easy to package nuclear power in a commercial language that can convincingly portray the continued spread of the technology as unalarming, much less rational. Alvin Weinberg foresaw this dilemma in 1972 when he pointed out that, while the probability of life-threatening nuclear plant accidents is low, expanded use of the technology will lead to an increased frequency of accidents and enlarged risks and hazards. He also recognized the conclusion to be drawn from right technical thinking of what needs to be done (1972: 33-34):

> We nuclear people have made a Faustian bargain with society. On the one hand, we offer – in the catalytic nuclear burner – an inexhaustible source of energy . . . But the price that we demand of society . . . is both a vigilance and a longevity of our social institutions . . . In a way, all of this was anticipated during the old debates over nuclear weapons . . . In exchange for atomic peace, we have had to manage and control nuclear weapons . . . [W]e have established a military priesthood which guards against inadvertent use of nuclear weapons, which maintains . . . a precarious balance between readiness to go to war and vigilance against human errors that would precipi-

> tate war . . . [P]eaceful nuclear energy probably will make demands of the same sort on our society, and possibly of even longer duration.

Secrecy and security considerations have always figured prominently in the case of nuclear technology, but their presence is typically assumed to derive from social demands for safety on the one hand, and protection against a military reversion of the peaceful atom on the other (the latter from concerns about "terrorist" sabotage to irresponsible state conversions of "civilian" programs). Weinberg's insight is to recognize the obverse purpose in garrisoning the Nuclear Project – to secure this technology from precipitous social abandonment. The fear within the technostructure is that ill-informed public officials, mass hysteria and contemporary Luddite orientations may combine in the aftermath of nuclear accidents to weaken social resolve and perhaps even foster irrational actions to dismantle the Project. By restructuring societies around an institutional complex managed by a technical and military priesthood, a reliable, stable social environment can be created in which 1,000 year nuclear security zones and 505,000 year social contracts, essential to the Nuclear Project, arise naturally to address the "nuisances" of atomic wastes and nuclear protest (Weinberg, 1979: 94-95; Anderson, et al., 1980: 30).

In sum, Chernobyl can conceivably facilitate the arrival of a Second Nuclear Era by serving as a means for eliciting consensus to tighten the hold of technocratic order. It may well bring forward actions which continue the process of replacing political with technical authority, strengthen the power of the national security apparatus, reassert an ideology of progress which devalues human autonomy, and prepare the way to the next stage of technological authoritarianism.

The reflexivity of technological value – that technology is evaluated within its own technical environment – poses a significant dilemma for social resistance to nuclear authoritarianism. Social values cannot be depended upon to threaten the Nuclear Project since they constitute literally alien sources of meaning and assessment. Technique's capacity to dominate other forms of social valuation stems from the Grundnorm of technological civilization: "Efficiency is a fact and justice a slogan" (Ellul, 1964: 282).

Conclusion

Technological progress in the contemporary situation is founded upon the prioritization of technical value over social value. If this ordering is not observed, progress either ceases, is set adrift, or becomes retrograde. As Ellul has succinctly put it, attempts at "moral conversion" of technicians or "moral intrusion" in technical processes only produce poor technicians and inferior techniques (Ellul, 1964: 97). For technological societies, at least as they have emerged to date, observance of the Grundnorm of technical valuation is essential. For such societies, the Grundnorm is not a theoretical abstraction or hypothesis awaiting empirical testing. It is a social truth which is itself subject to reflexive evaluation only. Indeed, members of a technological society do not know what it means to be technological and not observe the Grundnorm. How can we realistically investigate the future of nuclear power under the constraint of prior social considerations? Nothing will be *solved* so long as laymen's concerns are treated as authoritative in the design and assessment of nuclear research. Laymen may recognize problems with the use of a technology, but from the vantage point of the technological-military priesthood, ordinary citizens cannot know and cannot be relied upon to appreciate the solution to such problems. Social values can have little meaning apart from the technical in a technological society.

The ideology of technological progress "presupposes, normatively, that behaving in accordance with technical recommendations is not only desirable, but also 'rational'" (Habermas, 1974: 269). Neither the technical object nor the individual who fabricates it can be evaluated in autonomous moral terms as, the making of the atomic bomb illustrates. When asked if he or other scientists should feel guilty about the horror brought to Hiroshima and Nagasaki by the atomic bomb, Werner Heisenberg responded (quoted in Winner, 1977: 69):

> The word 'guilt' does not really apply, even though all of us were links in the causal chain that led to this great tragedy . . .[A]ll of us have merely played our part in the development of modern science. This development is a vital process, on which mankind, or at least European man, embarked centuries ago – or, if you prefer to put it less strongly, which he accepted.

Traditional sources of social evaluation are failing to challenge effectively the determinism of technological development. Rather than questioning the value of technology, modern thinking is preoccupied with whether society – its organizations, processes, structures, values, and its individuals – is adequate to the task of successfully accommodating technological possibilities. Literally, the value of technology is taken to be socially unassailable. Problems of value exclusively concern the evaluation of society. With regard to nuclear power, John Kemeny (chairman of the U.S. commission charged with investigating the Three Mile Island accident) accurately portrayed the modernist understanding: "The plants are safe: it's the people who aren't" (quoted in Hawkes, et al., 1986: 97).

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TARGETING CONTROL OF THE TOOLS OF EDUCATIONAL TECHNOLOGY AS AN AREA FOR CARIBBEAN DEVELOPMENT

Linda D. Quander

Introduction

In the light of the controversial call for a new world information order, it is extremely important to analyze the effect which new technology has on the education and training of Caribbean people in the diaspora. New technological innovations increase universal access to education through (1) providing individuals who are without easy access to an educational or training facility the opportunity to receive instruction; (2) enhancing methods to supplement the education and training of culturally different populations; and (3) extending the missions of resource limited institutions by expanding career choices and specialized training.

It is essential to remember that many Caribbean countries utilize technology outside the traditional formal school system through nonformal adult programs. These countries have educational needs that are not always related to the objectives of formal academic institutions. They have needs which focus on public information campaigns; motivation and mobilization; and literacy (AED, 1978). The conclusions from this analysis of the use of educational technology in the Caribbean support a tailored utilization of media in different settings in lieu of the blanket transfer of educational technology and methodology. The study proposes an assessment of contextual variables in relation to the extent to which Western technology is adaptable to issues in other domains.

A Bleak Past: Caribbean Conceptual and Technological Dependence on North America

Wilbur Schramm's The New Media: Memo to Educational Planners was commissioned to aid developing communities that wanted to design educational programs in light of experiences elsewhere. International organizations such as UNESCO noted the sometimes superficial success stories of educational radio and television in North America and Western Europe in the 1960's (Schramm, 1967). Using these success stories as models, many Western organizations provided generalized rather than customized technical assistance to Third World countries that were without sufficient classrooms and instructors (Schramm, 1967).

This wholesale adoption of Western instructional programs and technology exacerbated the persistent problem of an inequitable information flow. Western countries dominated control of instructional media because the United States and the United Kingdom developed most of the programs and trained most of the staff who were affiliated with the programs internationally. Foreign ideologies appeared in program content, planning and design. In an assessment of the power and potential of instructional

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technology, (1) who controls the medium; (2) how the medium is used; (3) for whom the medium is used; and (4) for what purposes the medium is used must be considered. Therefore, the conflict between Caribbean countries and Western industrial countries to control the flow of information affected the selection of the target audience; what was taught in light of political and cultural philosophies; and how it was taught in relation to educational methodology and economic factors.

National ideologies affected broadcasting, in general, and educational broadcasting in particular. Radio and television were seen as potential avenues to spark political awareness and to promote decentralization. Decisions to provide or not to provide radio or television services were political (Rogers, 1974). Control of broadcasting was assured through a variety of government agencies.

The Caribbean countries previously exhibited and, generally, continue to exhibit susceptibility to imported programs, techniques and their accompanying effects. In Haiti, French was the language used in the media and in the schools. The adoption of French culture demonstrated elitism for the mere 10 percent of Haitians who were literate and fluent in French (Walker, 1982). Literacy was much higher in Puerto Rico, Trinidad-Tobago, Jamaica, Antigua, and especially Barbados. However, these countries imported 80 percent of their entertainment and advertising which provided the bulk of programming that presented and validated a foreign culture (Walker, 1982).

The relative ease of the importation of programs was disproportionate to the difficulty of the production of domestic or regional programs. In 1980, the MacBride Commission Report and the UNESCO Program for the Development of Communication proposed that educational and informational uses of communication should be given an equal priority with entertainment. Controversial guidelines were introduced with respect to advertising and the values and attitudes it fostered. These guidelines stated that program content should be consistent with national standards, development policies, and efforts to preserve cultural identity (UNESCO, 1980). Unfortunately, the report was in practice a "wish list" rather than an accepted document.

In the area of education, the objectives and content of media programs which are developed to meet the needs of Caribbean countries should be adapted to the culture and background of the target population too. Blanket applications of educational technology often ignored this tenet. Differences in learning styles and previous instructional experiences were disregarded. For example, research demonstrated that when technology only reinforced formal lessons in developing countries, there was not a significant increase in educational effectiveness or efficiency. Ashby, Klees, Pachico and Wells (1980) found that with this type of use, the cost of television was prohibitive in relation to minimal increases in learning. In contrast, in Western countries where this pedagogical strategy was employed, research indicated a significant increase in learning.

UWIDITE as an Evolutionary Step Toward Regional Development of ITV

Traditionally, higher education in the Caribbean was obtained by those few who received scholarships to study abroad or by those who pursued a combination of work and study abroad. Today, a more numerous and diverse citizenry perceives higher education as a right rather than as a privilege or special effort. At the 1987 British Commonwealth Heads of Government Summit in Vancouver, Canada, there was a formal recognition of this right to access to university education and of the subsequent pressure on the limited, existing resources (Shridath, 1987).

The "Commonwealth University of the Air" (UWIDITE) was identified as a mechanism to provide access to and to relieve pressure upon the University of the West Indies (UWI). Sir Roy Marshall (1986) stated that the regional and international character of UWI was advantageous from many aspects, but it exposed the institution to centrifugal academic and political forces far more intense than those experienced by single state or national multi-campus universities. One of the more intense forces came from increased instructional demands from scattered non-campus and campus territories. Thus, the University of the West Indies Distance Teaching Experiment (UWIDITE) was a vehicle for (1) an aggregation of units into more economic sizes; (2) an encouragement to share human resources; and (3) a compensatory aid to alleviate problems of isolation. The third item was important as the brain drain from the smaller to the larger Caribbean countries, and from the rural to the urban setting within any one country is significant (Stahmer and Lalor, 1987).

The UWIDITE system was activated March 7, 1983. Prior to UWIDITE, Project Satellite was a 1978 two month instructional experiment. Following the relative success of Project Satellite, the three year Caribbean Regional Communications Study (CARCOST) was funded by the Latin American Division of the United States Agency for International Development (USAID). The major recommendation of the CARCOST study surfaced as a proposal for the UWIDITE system.

UWIDITE linked seven sites in six countries: the three main campuses (Mona, Jamaica; St. Augustine, Trinidad; Cave Hill, Barbados), a satellite campus at Montego Bay, Jamaica and the St. Lucia, Dominica and Antigua Extra Mural Centers. The program was funded by the USAID Rural Satellite Program. It was implemented by UWI with the Academy for Educational Development (AED) as the prime contractor. The planning, procurement and installation of equipment, and training of personnel were orchestrated by AED.

One of the customized rather than generalized approaches to distance education through UWIDITE is the avoidance of a British Open University strategy. There is a recognition that UWIDITE is an "outreach" from strengthened, not weakened, campus units. It is not a distinct open university system with independently funded and supported technology, etc.

In the antithesis of the UWIDITE philosophy, a blanket approach weakens campus units, and operating costs increase with insignificant increases in learning. Although the British Open University is viewed as a model system, Bates (1980) found other countries should use a variety of systems in order to tailor instruction. Therefore, distance education is successful when developing countries employ materials and a system of instruction which are responsive and relevant to local needs, culture and educational experiences.

Another customized approach to distance education appears through the areas adapted to UWIDITE. Every effort is made to present a variety of academic, adult education and public information programs in order to introduce a wide spectrum of individuals to the uses and potential of distance education. Examples of UWIDITE's variety of applications are the following courses leading to UWI qualification -- Certificates of Education for Teachers of Reading, Mathematics and the Hearing Impaired; Certificate in Public Administration; B.S. Part I Social Science Program; and Law Tutorials for Challenge Examination students and for possibly the full first-year program. Examples of courses not leading to UWI qualification and courses for outreach programs are Principles of Training for Day Care Personnel; Continuing Education for Doctors and Senior Nurses in Reproductive Health; Nutrition for Community Workers; Secondary School Science Laboratory Technicians Course to support laboratory activities in the schools; Radiation Protection; Microcomputers and Their Applications; FARMTECH '85; and Integrated Pest Management. Other uses of UWIDITE are administrative and faculty teleconferencing; inter-campus message transmission; medical consultations; and one-shot workshops.

Unfortunately, the major flaws of the UWIDITE system focus on issues of technical and economic access to and control of media. These flaws reflect the importation of expensive, and sometimes inappropriate, equipment. A standardized, wholesale transfer of Western technology ignores the importance of regional development of technology.

Furthermore, it ignores the escalating costs of technological transformation as a critical factor in the war of control of the media.

As a result, initial plans to operate small ground stations were scrapped because of the limited budgetary funds; the uncertain future of the ATS-3 satellite; and lack of access to other suitable satellites. So UWIDITE used commercial telecommunications carriers. There were approximately eight independent companies involved in a convoluted, confused system where identifying the source of disturbances caused delays (Stahmer and Lalor, 1987). The operational design and development of a regional system by one carrier would have been more effective. An additional complication was that stations (campuses) could not be linked selectively. All units were connected continuously.

Originally, there were no plans for visuals. Nevertheless, the UWIDITE system finally included slow-scale television, video cassette recording and playback facilities, and telewriters. The television units were purchased from Colorado Video Incorporated (USA). French manufactured telewriter units substituted for blackboards in the classrooms. However, problems with the telewriter were persistent: conversions for models were not good; spare parts were scarce; and innumerable minor faults existed (Stahmer and Lalor, 1987).

Other less serious problems also involved issues of access to, control of and cost of current technological tools. For example, an interactive telecommunications system necessitated a more extensive use of compatible word processing units among the various faculties and administrative units in order to be effective. Additionally, the Pulsecom Termination audio equipment was supposed to provide a privacy feature. This feature would have allowed two or more sites to speak with each other while excluding other sites. Efforts to have this device function properly failed. Yet, special scrambling equipment was installed in order to provide privacy for confidential discussions of budgets and grades.

Furthermore, switching back and forth between modes was worrisome. No voice line existed during visual transmission because a single channel was shared by both. The cost of a second channel was not feasible within the UWIDITE system. Technical designs which would permit the simultaneous transmission of voice and visuals via a single channel would be preferable (Stahmer and Lalor).

Identifying Cost as a Critical Factor in the War of Technical Control of the Media

Most developing countries rent INTELSAT transponders to satisfy domestic communication needs which are related to formal or nonformal education (Ashby, Klees, Pachico and Wells, 1980). The lack of incentive to become involved integrally in the domestic development of technology and programming revolves around the issues of access, control, and cost. The protests concerning equal access to electronic frequencies and geostationary orbits were, and continue to be, fiercely debated by third world countries and industrialized countries. These issues are related to the technical uses and problems of UWIDITE. All of the above provide an important history which dictates the nature of the relations in 1988 between particular agencies and Caribbean countries.

Industrialized countries continue to exert their influence as the controllers, producers, and distributors of communication equipment and programs. Although some technical equipment is cheaper, technological transformation is expensive. Third World countries, including Caribbean countries, do not manufacture communications equipment. Foreign exchange inequities exacerbate the problem. Caribbean countries cannot utilize outdated equipment when spare parts are unavailable. Places to train personnel on obsolete equipment are disappearing (Whitney, Wartella and Windahl, 1982).

The official call for a new world information order was issued in 1978 in a proposal by Tunisia. The General Assembly of the United Nations adopted a resolution which linked the establishment of the new international flow of communication with the quest for a new international economic order. The International Program for the Development of Communication was positioned within UNESCO to product infrastructures to reduce the gap among various countries in the area of communication.

In UNESCO's inter-institutional collaborative project on communication technology transfer, the areas of investigation included the development of local industries for the manufacture of communication equipment; the development of small-scale, low-cost communication systems; the effects of rapid obsolescence of hardware on developing countries' investment policies; the effects of imported programs; and the adaptation of training programs to national cultural modes of expression. In conjunction with these studies, a limited but promising action program was begun to identify specific components of technology which might lead to lower cost construction of equipment by developing countries. Unfortunately, the technical, economic and innovative components of this action program were not widely implemented.

Conclusion

The cause-effect relationship between education and economic growth is being disputed as Caribbean countries continue to labor under precarious political conditions, spiraling budgets, and the growing communication effects gap. Yet, the accurate assessment of the increased usage of instructional technology in developing countries must acknowledge that expensive and inappropriate programs were previously implemented in the wholesale transfer of technology and methodology. Programs did not account for contextual variables. There was a stifling importation of equipment, expertise, and programs. In the Caribbean, with the use of UWIDITE, there was an evolutionary step toward the customized approach to instructional technology.

The objective of this study was not to chastise those international agencies, foreigners, or domestic elites who have been involved in the implementation of imported programs. The aim was to encourage regional and domestic development of programs in order to use the power and potential of instructional technology. Significant results are then attainable.

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REGENERATING POLITICS AND TECHNOLOGY

Larry D. Spence

The steep pastures of West Virginia are laced with paths. The paths are cut out of the hillsides by the hooves of feeding cattle. Cows follow again and again their own trails until they create the paths. As a boy I found that the easiest, but not the fastest, way up a steep hill was to follow them. But to follow a cow paths was to twist and turn, seemingly without reason. I could see better, faster and more interesting ways to go. But the cow paths were there, gentle in grade and easy to walk. The habits of cows became my habits, as they had become the habits of my father and his father before him.

"Every machine contains a cow path," wrote the great American critic, Kenneth Burke. In every machine's design there are "variants of a process that remains simply because the originators . . . embodied this process in their inventions." The process may be improved or varied. But until it is named we are not equipped to choose between that process and another. Naming the process provides a cue, said Burke, for criticism and experiment. Without a name, "the process is a 'cow path,' in pious obedience to its secret grounding in the authority of custom."

Inventors are market-driven creatures. However novel may be their products, they accept, as a matter of course, what people want. Innovators are dependent on people of power to get their ideas into products in the market place. So they are even more responsive to what powerful people want. What people want is a product of the culture they learn and practice. What powerful people want is more determined by culture, since their station in society is based on customary structures and rules. Thus, some features of any new inventions are based on old beliefs.

Cars are not thought of or built unless there are roads. Roads come about because people have some place to go and some need to go there. All that presupposes territory, markets, property rights, and patent laws. Those are products of politics. Buying a new Chevy pickup is a purchase of a lot of political cow paths. It is also a submission to discipline. The truck must be paid for, so there are many hours of work. The truck runs on fuel, requires regular maintenance, must be insured. All that means more hours of work. With that level of commitment, the truck must be used. THe combination of hours worked to support the truck and hours expended to use and enjoy the truck eats voraciously into daily time. But time is freedom and thus the truck becomes a dictator.

Our technologies command and discipline us. The more technological the society, the more do political principles effect every action and object of an individual's life. Every product, tool and machine that enters our workplaces and our homes brings new demands on our time and our care. Intrusive technologies carry political decisions into every moment of our lives. But the paradox is: the more politicized the society in this technological way, the more invisible the politics.

To teach the understanding of technology we have to understand the political principles that drive it. Trying to assess, control or improve modern technology without employing political ideas and practices is fruitless. Trying to develop or improve technology in significantly new ways, without developing or improving politics, is impossible.

We don't look at it that way. So we end by blaming technology for political failings. Critics point to this or that undesirable effect of technology to no avail. By the time a device is around to criticize, much money and effort have been expended to see that it is produced and sold. Criticizing technology is a safe exercise like criticizing the weather.

There are two major political cow-paths in our technology. The object of invention, declared Senator Orville Platt in 1892, "is, first to enable man to satisfy his present wants with less of effort ...and second, to create in him the new wants incident to his higher plane of existence, and the means of supplying those wants, so that as the years go on man can have more of comfort with less of personal effort..."

Platt delivered his views at the Centennial celebration of the federal patent office. He identified more wants and less effort as the paths of our industrial technology. Only if a new device, process or product promises to lead to more -- more investment, more resources used, more subsidies, more jobs and more consumers, more input and more output, do we celebrate and promote it. Only if an innovation promises less skill, intelligence and effort do we call it progress.

"Expansion is the principle of our institutions," Edward Everett, the 19th Century orator governor, U.S. Senator and president of Harvard, liked to proclaim. An examination of the scanty records of debates at the Constitutional convention of 1787 suggests the federal government was designed to suppress democratic politics by distributing the landed wealth of the continent. The records suggest also that the government was designed to protect the wealthiest recipients of that largess. In turn the government was to be legitimated by the rule of the best men. Popular elections of a few offices guaranteed that the wealthy, the liesured and the intensely ambitious would rule.

The system of the founding politicians debased politics to a division of the spoils and selection of masters. Because the continent was rich beyond belief and the people spirited and independent this passed for democracy. But we pay for those political principles in the depletion of our natural resources and in the degradation of manual labor with its accompanying workmanship and ingenuity.

We strive in our national policies to create needs and destroy effort. These cow-paths are so basic to our understanding that they get no attention. Instead, we look for new ways to grow and new ways to avoid toil. If everything looks like a nail to humans obsessed with hammers, then everything looks like a frontier to humans obsessed with growth. Likewise, every device looks like a slave that will transcend the sweat and struggle of life. Today we discuss technology like it is a continent we will exploit on a genie that will magically realize our desires and fantasies.

We are in a dangerous place. Both our political institutions and our dominant technologies encourage our needs and ignore our capacities. The result of clamors for technological literacy and citizen involvement in technological decisions may be frustration. As one of my students said, "Every Science, Technology and Society course is a bummer." Technological literacy -- or more exactly, technological sense (in Richard Devons' happier terminology) requires political savvy.

But who wants to discuss politics? There is no subject less interesting and more suspicious to the average American. Traditionally Americans have taken the view that there are two ways to make money -- to work for it, by producing something or to take it, by going into politics. The semi-official definition of politics is "Who gets, what, when, and how." Politics is thus how to get something out of the government -- whether a career, a job, a subsidy, a grant, a guaranteed loan, a tax break or a welfare check. Politicians have honored this view by pretending they are something else. Even in 1787, they were careful to begin the Constitution without the damning confession, "We, the politicians . . ."

Most political scientists claim this notion of politics is an improvement over the view of politics as the coercion and manipulation of people for some ideal or the advantage of some ruling class. Since everyone gets something, so long as the pie of state expands, some even call it democracy. Since most citizens get bribed into apathy or enticed into careers of public greed, there is less need for state coercion and some consider it to be a politics of freedom. But given either view of politics -- as dividing the spoils or ruling the people -- most American conclude that politics is something dirty and try to steer clear of it.

I propose a third view of politics. Consider it as a secondary human activity having to do with starting, organizing, maintaining and sometimes ending the more fundamental activities of life. The primary activities of life, of course, are raising food and fibre, producing tools and utensils, building shelters, raising children, healing the sick and educating the ignorant. Politics concerns the way we divide these activities into tasks, the way we distribute rewards, the way we cooperate to get tasks accomplished and the rules and punishments we adopt to get the tasks done. This view of politics I liken to house work because it involves everyone, it never gets completely done and we take it for granted.

Recognizing defects in our views of politics doesn't mean we have to wait around for a revolution. The recognition is an opportunity to redefine politics. Rather than hope or shout for the government to solve our problems, we can begin to do it ourselves. How can academics contribute? By ceasing to think of ways to stifle or eliminate politics and by thinking about how to creatively expand citizen politics. That requires us to break with the traditions of political theory now taught in the universities.

Political thinkers long have worried over the cycles of history. Athens fell. Rome fell. Venice sank into the backwaters of history. The British Empire crumbled. The history of every kingdom, republic, federation or empire seems to show the same pattern. Political societies arise from time to time. With ingenuity they blaze to prominence. In a golden age they attract and teach the world. Then comes the slide into decadence until destroyed by revolution or the conquerer's sword.

Why does the cycle occur? Success brings wealth and power. Wealth and power cause corruption. The very strengths of a successful society -- its growth, its complexity, its luxury breeds a self-centered and power-hungry citizenry. In both the authoritarian and republican tradition of political thought the way to avoid the cycle was to design institutions that would maintain citizen virtue by stopping change. The idea was to liberate politics from history. The goal of classical political theory was to eliminate politics by reducing it to the rule of the wise. The goal of republican theory was to stifle politics by instuting a stalemating system of checks and balances. Of course neither solution works for long. So much political thought is focused on the rescue of states in decline.

For our founders, the way to rescue a decrepit polity was to regenerate it. George Mason, along with most patriots, thought the American War of Independence was a regeneration of the decaying British constitution. He liked to quote Machiavelli, who wrote that for republics to survive they had to time and again return to their first principles for rebirth.

If the principles are sound, they must be reasserted. If unsound, they must be reconstructed. But the notion often associated with political regeneration was a going back to a simpler, rugged, more wholesome and virtuous way of life to escape the decadence and corruption of the present. That is appealing, but hopeless.

Robert Rodale suggest a more promising way of thinking about regeneration. He is impressed with the way living systems respond to disturbances by becoming more resilient. Working with farms damaged by industrial methods of croping, he and his co-workers found that the capacity of the land rebounded when farming ceased. He began to study those regenerative tendencies. Different farming techniques based on those tendencies could be created he thought. Farmers have employed those techniques to substitute internal resources for external sources of energy, fertilizer and chemicals to create more sustainable and more efficient production systems. Rodale believes the same approach could be applied to other areas of life.

Applying his insights to the political cycles of degeneration gives us a hopeful perspective. Political societies aren't faced with ultimate decay. They are faced with the consequences of their own policies. Their problems are similar to the phenomenon of succession in ecology. Succession occurs in an ecological system when the growth and success of particular types of plants change soil conditions. With those changes the conditions become more favorable to different types of plants which thrive and succeed them.

For example, fast growing weeds will colonize quickly an abandoned field. The weeds stabilize erosion. Their quick growth and decay build the soil. The new conditions favor slower-growing but more efficient plants and bushes. In turn, as the field is stabilized and enriched, even more slowly growing, but more enduring trees will flourish.

A.J. Lotka stated the principle that governs succession. It says that living systems win in competition for survival that maximize the use of available energy. When there is unused energy in an environment, those systems will win that grow quickly. They will survive even if they are wasteful, for the principle dictates the rule, "grow or die" under those conditions.

But when available energy -- sunlight and soil -- has been tapped, those systems will win that are more efficient in their use of energy. Unlike the fast-growing weeds, those systems are more complex, more diverse and more stable. They win, even though slower growing, for the principle dictates "efficiency or death" under those conditions.

If something like Lotka's principle applies to political societies, then cycles of degeneration occur because successful systems transform their environments. They not only use up natural resources, they create roads, cities and machines. The success of growth encourages needs and aspirations in its population to drive that growth. It creates institutions built on expansion and principles of greed. The very success of the old ways makes them hard to change. Since they have worked, reasonable people don't want to abandon them? Tempting is the notion that people no longer live up to the virtues of the founding principles. To try to live up to those principles by searching for new areas of growth exhausts the resources of the nation. To try to get people to live up to those principles through renewed efforts of indoctrination stifles creativity.

Metaphorically, we can see our political and economic institutions as weeds of simple internal structure but vigorous growth that captured the energy sources of the frontier. They embody the principle, "grow or die." According to that principle, Pratt was right in arguing that a man without needs was useless. According to that principle that Constitution's authors were right in creating a government that fostered those needs and promoted the rule of a liesured elite.

Now the continent is full. The sources of energy mostly are known and tapped. The windfalls of topsoil, forests, accessible minerals and grasslands are gone. Rather than lament the passing of the frontier we need to respond to the challenge of these new conditions. We need to design diverse, complexly structured, and efficient local governments, business interprises and voluntary associations to better use our internal resources. The principle of these institutions will be less, different, cheap or local inputs while maintaining or increasing output. That principle will require a renaissance of invention and enterprise.

The new institutions will grow, but not like weeds expanding rapidly to tap any available energy source. They might proliferate in diversity by adapting more precisely to local and regional conditions. Such institutions will rely more upon the capacities of their members -- their ideas, their discipline and their care -- than the large-scale application of coal, oil and nuclear power to drive production. They will require more of a people than obeying, voting and wanting. We sense this requirement when we talk of a new age of information and of the need for a better educated citizenry and workforce.

The basic idea of regenerative politics is: people can develop their moral faculties only by using them.. When we let or try to get others to decide for us what is right and wrong and what is best for industry, for our defense, for the environment or for our families our capacity to judge begins to atrophy. The urges of freedom to decide and act dry up. We can try to retain what freedom we can in our private world. But we sacrifice our opportunities to become mature. Within our playpens we can act and we can decide but only as clients and consumers, not as citizens and producers.

New stories and polls are reporting an insurgence of local citizen activity in the 1980's. But activist citizens have yet to say what they represent or what they are trying to do. Citizen movements say "stop" to the excesses of growth policies in government and industry. But so far, despite their energy and their victories, they say little more. Needed is a language, not of protest, but of building. Regeneration can supply the framework of that language.

More than any other human activity, politics is about words and talk. "As we define politics, so we behave politically," writes Heinze Eulau, "for our definitions of politics. . .determine, at least in part, what we observe and how we explain it." Our first task in regenerating politics is to initiate new talk about our capacities as citizens. We need to talk to each other in ways that are not derisive of politics.

Cow paths are routes of ease, unless they take you places you don't want to go. As Burke wrote, to see and name them opens the adventure of alternatives. New routes require that we discuss and decide our destinations.

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TECHNOLOGY LITERACY AND THE ETHOS OF DEMOCRATIC GOVERNMENT

Joseph Haberer

During the American constitutional bi-centennial, almost none of the public discourse focused on the impact of technological change on the contours and character of the American democratic polity. These 200 years have seen a great many changes triggered by developments in scientific knowledge and its applications. In what ways technology infused changes have transformed the American political system is a topic that deserves far greater consideration than it received during the celebrations.

To understand the connections between literacy, technology in the American historical context, three watershed periods merit attention. First, the founding period, associated with the Framers of the Constitution, on the one hand, and the Jeffersonian populists, on the other. Second, the critical period of nation building, embodied by the spirit and practices of the Jacksonian era, up to the civil war. Third, the post-civil war decades which brought with it the development of the modern, corporate, industrial nation-state.

The tension has been between the anti-democratic (but republican) Federalist, and the democratic Jeffersonian populist vision of American society. This struggle between two perspectives about the American future continues. The former is suspicious of democracy, concerned with liberty, embued with conservative values, believes that the educated and propertied class should govern. It gravitates toward a Hobbesian view of the world. The Jeffersonian view is based on a more positive, Rousseaun view of human nature. It believes that citizens be actively involved in shaping decisions that affect their lives. It encompasses both a distrust of the urban world of big cities and a fear of economic centralization.

Of considerable relevance is the question of what explains variations in citizenship practice during the last two centuries. Technological literacy relates in some ways to the broader issue of what engenders the necessary and sufficient conditions to make democracy more viable to speak, for and within the American national psyche.

What appears clear from the record is that throughout this history there has been a consensus on the necessity of some form of literacy among the population, and even more so of the primacy of technological literacy, namely the value of having technical skills widely diffused among the citizenry. Whether for the purpose of augmenting the virtues of a Jeffersonian yeomanry, or the buttressing of national economic development of a Federalist vision, Americans have always seen technological knowledge and skills in positive terms. Within these watershed periods there remains also a tension between an emphasis on economic and technical development, on the one hand, and human development, on the other. The issue that is typically touched upon only peripherally is what ends technological literacy should serve.

There are several salient issues that confront us to which we ought to give much more attention. **To what ends is a given technology or the technological system itself linked? What values are being served? What is the connection between technological and political literacy? What transformations are taking place due to the impact of technologies? Specifically how are these affecting the democratic polity and its ethos?** In any useful debate about the connections between technological literacy and American politics these are questions which can provide a handle for better understanding.

What is the relationship between technological literacy and democracy? In an earlier paper I argued that technological literacy should be subsumed under general literacy, particularly when we consider the humanizing function of education. Technological literacy in our social order is seen primarily as having an instrumental value, rather than an intrinsic one. Even within this instrumental nexus, literacy is valued in a narrow functional way, important for specific purposes such as economic competitiveness, maintaining our edge in R&D, and so on.[1]

The widely held view that the greater the level technological literacy in a given society, the more likely that it will tend toward democratic norms is a dubious one. Given 20th century developments in industrialized societies such as Germany (Final Solution) and the USSR (Stalinist modernization via the Gulags) it should be clear by now that there is no necessary link between literacy, technology, and democracy. At best it could be argued that in the modern world literacy itself, and technological literacy specifically, is a necessary condition for an effective, responsive and democratic system to operate; obviously it is nowhere near a sufficient conditions. Under what conditions technological literacy enhances democratic propensities is another question that merits further study.

How is one to judge American democracy today? How does it compare to earlier realities? I think a case can be made that within the last 150 years,as we have become more developed, technologically sophisticated and industrially developed, there has actually been a considerable loss in political literacy . The high level of ignorance about public affairs, substantial voter apathy, and increasing alienation attest to problems. A comparison between contemporary political debates and those, for example, between Douglas and Lincoln,reinforce that conclusion. The elements that have contributed to this decline are arguable, and no doubt multicausal.

Technological developments themselves--the creation of new machines and the complexities that emanate from their entry into society--very likely have also been a contributing factor of some importance in bringing about a decrease of democratic/political understanding and involvement. The universe we now inhabit appears often much more complex to grasp and deal with. Complexity, however, is not the same as mystery. Too often people act as if knowledge and power derived from scientific /technological developments are accessible only to specialists and "brilliant" people. Little is done to disabuse most citizens of this misconception.

In the pluralistic, interest group oriented political order operative in the United States, command of the technological options gravitates to economic, social, and political elites. C.Wright Mill's notion of industrial, military, and political power elites making the key policy decisions in our social order has much evidence to support it.[2] In such a system it is among the "better educated," which means the more trained elements, that technological literacy is likely to be most established and most valued. For the bulk of the citizenry, the primary socialization is toward becoming conforming performers in the work place and pliant consumers in the "private" sphere. The political domain increasingly becomes a mirror image of the economic one: a market-place approach dominates the territory. Most of the shaping of the direction which technology takes, or the uses to which it is put, remains in the hands of experts and the elite groups they serve in the corporate, military and political sectors.

Knowledge is a form of power. In a technologically advanced society technological knowledge and understanding is a formidable means of control. We tend, however, to confuse factuality (information) with knowledge Information, however, is a relatively low species of knowledge. What is required in citizens' education is the ability to analyze, conceptualize, reflect, in short, the capacity to think. Most of our schools encourage this sporadically, and usually do it badly. The failure of our educational institutions to perform well in the area of making citizens may be an indication that the underlying inner logic of the system is precisely to keep the bulk of the population from actively participation in the political process.

In what ways is technological literacy an element in establishing or maintaining a viable and vital democracy in the modern era of mass-societies? Very little attention is given in public discourse of how such literacy might enable citizens at all levels and in all classes to better understand technology infused issues so as to encourage and create conditions where they will more confidently participate in meaningful ways in the political and social process.

Any significant enhancement of democracy entails the sharing of decision-making among much larger elements of the population. This requires a significant redistribution of political and probably (in the long run) of economic power. Among the affluent and better positioned groups/classes in our society there is no discernable interest in bringing about such an enhancement of democracy. Rather, there is the habit of engaging in symbolic reassurance.[3] Technology literacy for most Americans means sufficient fluency in the language of technology to be able to function in an industrial and consumerist society.

The fundamental problems here are systemic. There is no conspiracy. But a sufficient community of interest exists so as to diffuse, weaken, and "tame" the democratic spirit. The end result is to make it manageable and manipulable. Those groups or classes that are in the key positions--who run our society, who administer it, can do so in terms of their own perceived self-and national interests. Thus is avoided the dissonance, or the intrusion of an active democratic populace.

Nonetheless, the democratic spirit, as well as the populist impulse is still alive. It is decentralized and local, poorly organized and sporadic. For the most part it still lacks a compelling rhetoric a persuasive ideology and high visibility. In a society in which the equivalence of bread and circuses (consumerism and entertainment) is the mainstay of the social agenda, the Jeffersonian impulse faces large obstacles.

Technology has its own imperatives and its infusion into society creates new problems and opportunities for citizens in a free society. Examples of this are the impact of the computer, xeroxing, cable television, each of which has potentials for supporting broader based democratic political participation. However, we generally leave these matters to a diffuse social will, or to the purported impersonal forces of the market. The issue becomes of how we are to make technologies work for the enhancement of the democratic will. To bring this about will require diffusing these and other emerging technologies through the society in such a way that they become explicitly linked to the goal of a broadened citizenship. Technology itself, and certainly technology literacy, can be viewed as one of the enabling elements that has the potential to propel us into new directions for democratic participation. But such technologies, for example, C-SPAN--have only a potential for such movement, not its certitude. Positing a truly democratic society, a community of citizens, of more equitably shared power, would entail a process of profound transformations. The forces of inertia and resistance to such a change are, of course, formidable. But they are not insuperable.

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THE IMPORTANCE OF INTERACTIONS IN BROADENING THE BASE FOR DECISION-MAKING ON TECHNOLOGY

Joske Bunders and José van Eijndhoven

Introduction

Broadening the basis of decision-making means involving more actors and more aspects in decision-making processes. At present decision-making processes relating to technology have become institutionalized in such a way that only certain actors participate and certain aspects are taken into account. However, owing to the controversies concerning technology which have arisen mainly since the 1960s, the legitimacy of this institutionalization and of the technological options that are involved has been called into question.

Attempts have therefore been made to bring about a closer involvement in these decision-making processes of actors and aspects that previously were involved only marginally. Several initiatives to involve more actors in decision-making were discussed in the OECD-report "Technology on Trial" (1979). Almost ten years have passed since the publication of Technology on Trial and much more experience has been generated through all kinds of initiatives to enhance public participation or to broaden still further the basis for decision-making on technology. Therefore it is worthwhile evaluating how and under what circumstances initiatives to broaden the basis for decision-making on technology can be effective. This is especially of interest because in Technology on Trial a number of problems were observed that may act as barriers against this broadening. In this paper we present the results of four case studies of initiatives to involve new actors in decision-making on various technologies. The topics of the case studies were the nuclear energy debate[1] (more specifically the Broad Social Debate held from 1981 to 1984), soil pollution and its clean-up[2] (with emphasis on the role of citizens' experts), technology agreements in information technology[3] and the role that environmental groups and groups concerned about third world problems play in the development of plant biotechnology[4].

Attempts to Broaden the Basis

Decision-making in the field of technology is not a process that is characterised by certain clear-cut decisions; it should be seen rather as a continuous process during which slight adjustments are made continually as a result of minor decisions; in each of these decisions the institutions and actors involved can change.

In a decision-process some actors (the primary actors) are involved but others are not part of the institutionalization (the secondary actors). An initiative to broaden the basis for decision-making attempts to involve the latter. If the attempt succeeds a new decision-making situation has arisen.

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[2] R.Weterings and J.v.Eijndhoven (1987) and Rob Weterings (1987)
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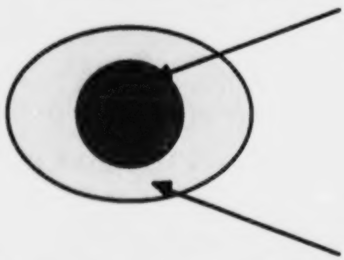
Decision-making situation



Initiatives aimed at broadening the basis for decision-making often start because secondary actors are dissatisfied with the possible effects of current policy. For instance, a stated intention to increase the number of nuclear energy installations, to take measures to deal with polluted soil, to introduce new technology that would possibly influence the quality and quantity of labour as well as stimulation of research to enhance the resistance of plants to herbicides have all led to alarm amongst groups that were not involved in the decision-making process but would nonetheless be confronted with the effects.

From the case studies we conclude that the secondary actors mainly use four types of action in their attempts to broaden the basis for decision-making.

1 Attempts to delegitimize the activities of other actors

When a policy option is delegitimized, one actor criticizes some of the values and interests of the adversaries or emphasizes that certain options are contrary to his own values and interests. The actor actively searches for technical uncertainties and controversies to illustrate problems connected with the realization of certain options. To be able to demonstrate uncertainties and make controversies explicit one needs to have the necessary expertise at hand. Uncertainty about the criteria that will play a role in the decision-taking is an important barrier that prevents secondary actors from directing their activities to topics that are relevant for this purpose.

2 Development of a view on the problem and on a proposal for a solution

If an actor strives to influence the decision-process, in most cases it will not suffice to delegitimize the proposed policy option, but a different option has to be developed too. The main starting points for the development of such an option are the actor's own values and interests and scientific information (to answer the question what is wanted and what can be done). Secondary actors will have to devote a great deal of attention to uncertainties and controversies.

3 Activities aimed at joint problem solving

Activities that are frequently used to influence decision-making are: entering a debate, cooperation or negotiation.

In negotiation, values and interests of the other actors are hardly criticized. The actor's own values and interests are an important aspect in the negotiations, but uncertainties and controversies that are used to manipulate the options of the other parties also play an important role. Specific expertise is of major importance for the success of these activities.

As soon as cooperation is achieved, uncertainties and controversies play a role just as in the situation where one actor develops his own solution, the difference being that the solution being proposed by the coalition will have a broader societal basis. A broad societal basis for a proposed policy option of course impedes the delegitimization of this option by others.

4 Activities aimed at informing and mobilizing support

Such informing and mobilizing activities can have different aims. These include:

1) Informing people to enable them to form an opinion;
2) Informing people with the purpose of enhancing or reducing the societal basis for a certain policy option;
3) Informing people of the way decisions will be taken for the purpose of legitimizing or delegitimizing the existing decision-taking structure.

In activities aimed at informing and mobilizing, often the actor's own problem definition and his own solutions are presented.

In all initiatives to broaden the basis, which we studied the activities of informing/mobilizing and of formulating the actor's own options occur in one form or another. These activities seem to be crucial for most initiatives even if the possibilities for these activities are slight or if the main activities are otherwise directed.

Delegimitizing a policy option of a primary actor seldom occurs along with negotiation.In a fierce struggle negotiation seems out of place, as was the case in the nuclear energy debate. Therefore initiatives to broaden the basis can be divided into two categories: initiatives directed at delegitimation and initiatives directed at negotiation and cooperation.

A New Typology for Decision-Making Situations

An interaction that is characterized by delegitimizing activities coupled with information provision and mobilization activities can be described as being *antagonistic*. Another type of interaction aimed at achieving negotiation or even cooperation, likewise supplemented by information and mobilization activities and the development of an option, can be described as *symbiotic*. Symbiosis and antagonism are interaction types that develop in time. Symbiosis can evolve into antagonism and vice versa. But at a chosen moment in the decision process the decision-making situation can be characterized either by the term symbiosis or by the term antagonism.

Symbiosis and antagonism are two characteristic situations on a continuous scale (Mastenbroek, 1980), a scale that indicates a measure of cooperation between primary and secondary actors. Negotiation can be viewed as a strategy in which struggle and cooperation alternate. The degree of cooperation between primary and secondary actors can be seen as one dimension of a decision-making situation.

Van Eijndhoven et al. (1987) gave an inventory of aspects that can vary in decision-making situations in which initiatives are taken to broaden the basis. The aspects considered were the technology (phase of development, the extent to which the the technology develops autonomous, diversity of applications), the decision-making situation (actors and their dynamics, the decision arenas involved, the role of (non)information, the institutionalisation) and the type of initiative to broaden the basis. One of these aspects varies considerably among our case studies and also seems to have considerable consequences for the way an initiative to broaden the basis fares and for the way in which it can be optimized. This aspect is the degree to which the patterns of interaction between actors in the decision-making situation at hand are institutionalized. Therefore we also classify the decision-making situations according to this second dimension, namely the *degree of institutionalization* of the decision-making situation.

For instance, the patterns of interaction between employers and employees have become strongly institutionalized. In this institutionalization some aspects of the position of employees are debated and others are not. These interaction patterns become very clear as soon as employees try to influence decision-making concerning technological change in a firm. There are also fixed interaction patterns in decision-making on nuclear energy. In such a strongly institutionalized situation some actors are involved in the decision-making and others are not. Such fixed patterns can generate specific starting-points to broaden the basis for decision-making, especially when there are communication channels via which the discussion of problems of secondary actors can be discussed. However, these fixed patterns can create specific barriers. Fixed patterns can lend respectability to some policy options, but may keep other options off the agenda (Glasbergen, 1984, p.68).

In contrast to these strongly institutionalized decision-making situations, other situations

such as those occurring in soil-pollution or plant biotechnology are hardly institutionalized at all.
In soil-pollution situations in The Netherlands citizens can be represented on a provincial committee, but there are large differences in the access of secondary actors to these committees and, accordingly, in the influence that the citizens exert in the decision-making process. Therefore one cannot speak of a fixed form of institutionalisation. Routines to deal with soil pollution situations are still evolving.
Environmental groups and groups acting on behalf of third world citizens with respect to plant biotechnology likewise find themselves in a situation without firm institutionalization. Networks involving actors interested in the development of this technology have formed rather recently and as yet show no fixed decision-patterns.
These differences between the cases indicate that a decision-making situation can be characterized according to the measure of institutionalization involved.

The two dimensions, namely the willingness to cooperate between primary and secondary actors and the measure of institutionalization, may not vary completely independently, but can still be distinguished analytically. Therefore these dimensions can be used to construct the following typology.

Typology of decision-making situations

degree of institutionalization

degree of cooperation		*high*	*low*
	low	1 **antagonism in an institutionalized arena,** e.g.: nuclear energy, some interactions between employers and employees	2 **antagonism in a non-institutionalized arena,** e.g.: some interactions between inhabitants and government in soil pollution situations
	high	3 **symbiosis in an institutionalized arena,** e.g.: some technology agreements	4 **symbiosis in a non-institutionalized arena,** e.g.: interaction plant biotechnologists with secondary actors, some interactions of inhabitants and government in soil pollution

Four different types of decision-making situations have been generated by this typology, each of which shows different patterns of interaction between primary and secondary actors.On the basis of the results of Technology on Trial and of literature on organisations we can expect a number of barriers to arise in initiatives to broaden the basis for decision-making on technology, namely the existing institutionalization, procedural and technical uncertainties, and lack of expertise. Therefore a key question is how in different kinds of decision-making situations these barriers play a role in initiatives to broaden the basis for decision making and how they can be dealt with. If we can find an answer to these questions we may obtain insight into the circumstances under which these barriers can cause problems as well as get an indication of how to anticipate the problems. In the next three sections we will discuss the three main barriers we found.

Lack of Possibilities for Effective Interactions

When the primary actors aim at stimulating a technological development and secondary actors aim at control, there is a conflict of interests. This conflict can lead to minimal interactions between actors. This will be a barrier to the effectivity of the secondary actor's activities.

The context of a decision-making situation is indicative of the interaction patterns that may be expected[5], but these patterns are not necessarily the best ones to ensure that secondary actors will make a substantial contribution to decision-making. Therefore we must first determine the best type of decision-making situation to broaden the basis for the decision-making, and secondly find out how this type of decision-making situation can be reached.

In general, forms of cooperation seem to be more effective than antagonistic forms of interaction, except when parasitism occurs. Parasitism is a situation in which secondary actors have to sacrifice something (for example they consent to the introduction of new technology since it will ensure the continuity of a firm) without getting anything in return. The best option for them in that case may be to quit the negotiations and try and delegitimize the options generated by the primary actors. This behaviour can have a positive effect on the decision-making situation as long as it is only the policy option that is delegitimized and not simultaneously the behaviour of the decision-makers. One must however realize that it is easier to move from situation 3 to situation 1 than vice versa, therefore one should not enter upon this course light-heartedly.

By opting out of the negotiations the secondary actor delegitimizes the policy option of primary actors and may return to the consultations with a little more power, as was demonstrated in the soil pollution case. Such a process is more likely to occur in decision-making situations with little prior institutionalization, where decision-patterns still have to evolve, than in strongly institutionalized contexts. Still there may be situations where such a strategy can be used profitably.

Even in situations where cooperation seems profitable for all or most of the parties involved, interactions between actors can be counteracted if primary actors have a negative view of the attitude of the secondary actors. In the case study on plant biotechnology some biotechnologists were very reluctant to cooperate with environmental groups, because they had had former negative experiences with these groups. In this situation an intermediary was used to lower the barrier. By discussing other people's experiences and assessmentsof the situation the intermediary was able to present the biotechnologists with other perspectives. This new information made it simpler to surmount the barrier between decision-type 2 and 4.

Lack of cooperation can also stem from strong social dynamism in a technological development. This dynamism makes it more difficult for primary actors to involve secondary actors, even if such involvement would seem desirable from the point of view of averting extra social costs. One of the reasons for the difficulty is that the actors initiating the new technological development are very occupied with creating the conditions that will permit this development. This often involves the creation of new interaction patterns which include the actors that make the development possible.

In the first phase of the development of plant biotechnology, for instance, new interaction patterns were created between researchers from university and governmental laboratories, managers from industry and civil servants from the ministries of Science and of Economic Affairs. These primary actors made no attempt to interact with other actors, and the latter had no inclination to contact the primary actors, because there was much uncertainty about possible adverse effects of the new technolgy and they had very little expertise. Although they may seek to influence the decision at an early stage they do not see ways of doing so. In these cases an extra effort is needed, preferably on the part of the technologists themselves, especially if they are disquieted, because they know most of the possible effects and can therefore have an early warning function. Not many people are needed to bring about interaction at this stage and in this situation. In the case of plant biotechnology one intermediary in an independent position was able to generate interaction between researchers and secondary actors. This interaction in turn led to new research options.

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[5] For a description of the circumstances under which each of these four interaction patterns are likely to occur: see Joske Bunders and José van Eijndhoven (1987).

The creation of informal information channels seems to be one of the most important ways of generating cooperation. This precludes the persistence of decision-making situation 2 in situations where situation 4 generates more options for secondary actors.

The transition from high to lower degrees of institutionalization can also be utilized for the purpose of optimizing the decision-making situation. The Dutch Broad Social Debate on Energy Policy can be seen as an attempt to de-institutionalize the strongly institutionalized decision-making situation around nuclear energy. During this debate many different social groups were invited to express their views on future energy provision in The Netherlands. Of these groups some had been involved in the energy-debate before, but many others had not.

De-institutionalization of course does not mean that previous power relations have terminated. This is obvious from the fact that after the debate had finished the Dutch government proposed building some new nuclear energy facilities, which was contrary to one of the main conclusions of the debate. (The Chernobyl accident led to postponement of a final decision.)

Procedural and Technical Uncertainties

The procedural and technical uncertainties will influence the options that actors choose and the activities they conduct. Feelings of uncertainty may make the parties involved more open, but will often make them choose poorer options.

Uncertainties and controversies can diminish as well as enhance the accessibility of secondary actors to decision-making processes. If success seems certain, primary actors will see no advantage in cooperating with others and the only possibility left for secondary actors is to influence policy by delegitimizing activities. Secondary actors will have fewer opportunities to cooperate if primary actors have already reached a robust consensus[6], or need to reach a consensus to be able to develop the technology (for instance because the scale of the technology forces many actors to cooperate).

To prevent uncertainties from acting as a barrier to broadening the basis of decision-making, one has to take into account the existence of these uncertainties and the influence that the uncertainties have on the decision-process. In studies of agenda-building[7] one finds that only a limited number of issues reach the formal agenda. The neglect of options and problems is the rule rather than the exception; in general, topics that are prepared for the agenda during negotiations with primary actors or in cooperation with them have a much better chance of getting to the agenda than issues that are formulated by secondary actors alone (Glasbergen, 1984, p.26 ev.). Negotiation and cooperation therefore seem to be important strategies for getting new issues or options on to the agenda (which again stresses the importance of decision-making situations 3 and 4 over 1 and 2). Cooperation and negotiation are all the more important because studies of agenda-building show that there is no direct relation between perceived social problems and policy. Schattschneider (cited by Glasbergen) formulates this as follows:

> "All forms of political organization have a bias in favor of some kinds of conflict and the suppression of others, because organization is the mobilisation of bias. Some issues are organized into politics while others are organized out".

In the procedures to be followed special attention should be given to the effect of uncertainties. The study of the Dutch Broad Social Debate on Energy Policy shows that some of the secondary actors evaluate the effectiveness of their activities positively, from the point of view of mobilizing interested persons, but not from the point of view of a linkage to parliamentary decision-taking. This phenomenon was described as follows by one of the environmental groups:

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[6] Robustness is a term used by Arie Rip to denote the difficulty of making actors stop supporting accepted views.

[7] Studies of agenda-building concentrate mainly on formal agendas of governmental institutions. Results of these studies therefore cannot directly be used when decision-processes in industries are being discussed.

"An important defect has been that the procedure was directed mainly towards developing arguments and not towards evolving a procedure that would link the arguments to the decision-making."

Closely related to this procedural problem is the question of how 'broad' the issue of a debate may be if it has to be linked to decision-taking. In the primary phase of the energy debate secondary actors put great effort into widening the issue, as a result of which their problem definition fitted into the framework of the debate. According to another environmental organisation it was this breadth which caused problems in the relationship between the outcomes of the debate and decision-making.

The criteria that will play a role in decision-making constitute a major problem.Uncertainty about the criteria with which primary actors will enter into the decision process prevents secondary actors from concentrating on topics that are of relevance for the decision-making. It may be of importance for secondary actors to have a broadly formulated topic, although this may mean that all attention will be directed towards aspects that play a minimal role in the decision-taking. Therefore it may be wise to choose broad issues first so that secondary actors can make a contribution.The issue however has to be narrowed down again during the process of opinion forming and decision-making to those elements that will be criteria for the final decision. Such an approach has been followed in the case of plant biotechnology. First of all the problems of secondary actors were inventorized and then areas were demarcated that could lead to a fruitful discussion between primary and secondary actors.

We can conclude that especially in an uncertain and badly defined situation secondary actors make progress by jointly elaborating potential issues for the agenda, because this will make it considerably easier to get these issues on the agenda. In some cases secondary actors can benefit by utilizing decision making arenas other than those normally involved.

Lack of Expertise on the Part of Secondary Actors

The crucial role played by expertise was clear from the activities of the secondary actors. If expertise is lacking, participation of secondary actors can lead to decision-making situations in which known and in principle accepted knowledge is not taken into account. This in turn leads to unsatisfactory arguments.

Secondary actors, more often than primary actors, are not in the possession of detailed analyses of a technological development, are not aware of the possible options it represents and do not have the experience that can help them to influence the decision-making process concerning technology. When secondary actors wish to participate in the decision-making process, ideally this inequality should be removed or at least counterbalanced. Information provided by primary actors is often distrusted and can therefore only be employed profitably in situations where distrust does not hinder communication. Another route for secondary actors to acquire expertise can be opened up by providing them with the means to elaborate and underpin their own views and to distribute the information that is generated in this way.

Olson (1965) listed the characteristics of (action) groups that have been able to effectively influence decision-making. It is especially when these characteristics are lacking that the help of experts seems to be crucial. In our case study on soil-pollution the lack of technical expertise in a group and the lack of political experience in the decision arena were identified as the main factors weakening their role in the decision-making. These obstacles can be reduced with the help of experienced advisors.

In the nuclear energy case an initiative to counterbalance the unequal position and knowledge of the participants was evaluated. The participating groups were provided not only with means to distribute information but also with means to elaborate and underpin other views than those that had been at the basis of government policy. In this initiative the financial capacity of a group asking for support was used as one of the criteria for awarding grants It is concluded from this study that this initiative did indeed act as a help to counterbalance the unequal starting positions of participants.

Expertise can be generated by the secondary actors themselves as often happens in industry (trade unions), but can also be generated by external advisors. Different types of advisors seem to operate and be effective in different decision-making situations.
Technical information is important in all types of decision-making situations concerning technology, but the importance of having one's own experts may vary. What seems to be of primary importance is whether the secondary actors trust the primary actors. If the primary actor is to be trusted, the secondary actor can use the information supplied by the primary actor when a joint policy option is being developed. Complete lack of expertise, however, can make even this way of operating fruitless.[8]
In activities aimed at delegitimizing policy options, knowledge plays a greater role. Criticizing technical reports requires technical knowledge. If an actor wishes to delegitimize policy options on the basis of deviant information, knowledge in most cases has to be supplied by specialized experts, preferably experts with a high status, such as advisors from an independent engineering office.
In negotiations too it is important for secondary actors to make use of technical information because this reduces the risk of being sent away with a superficial explanation intended to keep them quiet. Additionally technical expertise can make it easier for secondary actors to defend profitable options.

The amount of institutionalisation in a decision-making situation seems to influence the type of information that secondary actors need. In strongly institutionalized situations procedural knowledge is of the utmost importance. Many environmental activists have much knowledge of and experience with public enquiry procedures. This seems to be one of the reasons why in some cases citizens' groups ask them for help.
As we mentioned before, an intermediary may be in an excellent postion to further communication between primary and secondary actors who were not in contact before. But in strongly institutionalized contexts an intermediary may function as a go-between between primary and secondary actors, especially with regard to starting or instituting cooperation.

The above assessment of the information-need generates speculations about the type of expert that seems to be best equipped to remove information-barriers in various decision-making situations. In the literature one finds descriptions of the various roles that technical experts can play in advising secondary actors. In the soil-pollution case some of these roles were redefined and one new role was added. The types of experts that could be discerned were:
-*the advocate*. This type of expert gives technical information and technical support, but continues to interact formally with the group he is supporting;
-*the emancipatory expert*. This type of expert acts more or less as a member of the group he supports, and advises both on technical and strategic matters;
-*the activist*. This type of expert acts as a coalition partner for groups which for the time being have interests in common with the activist; to further their joint cause the activist will support groups with technical and strategic advice.
In the plant biotechnology case we introduced a new type of advisor, whom we called an *intermediary* or *boundary spanner*.
Our experience in the case studies has taught us that activists and advocates will play a role particularly in those decision-making situations where the interactions between actors are antagonistic, whereas in situations with a larger degree of cooperation intermediaries and emancipatory experts will be more likely to compensate for the lack of expertise on the part of the secondary actors.

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[8] Compare the case on plant biotechnology, where plant biotechnologists expressed the opinion that environmental groups and groups concerned about third world affairs do not need much expertise, but that 'no expertise' would make it impossible to explain why things happen as they do, e.g. why plant biotechnological options developed so slowly.

Lowering the Barriers for New Actors

In the above discussion of barriers that secondary actors have to surmount before they can actively contribute to decision-making processes we mentioned some possible ways in which barriers might be lowered.

Optimization of the decision-making situation and stimulation of interactions

The context of a decision-making situation concerning a specific technology gives an indication of the probable interaction patterns, but these are not necessarily the interaction patterns that will enable secondary actors to contribute to the decision-making process. Therefore on the one hand one must determine what type of decision-making situation is best and on the other hand how this type of decision-making situation can be generated. Profitable forms of interaction can be hindered by negative views that actors hold about each other, whether these are justified or not.

In general, forms of cooperation seems to be more profitable than antagonistic forms of interaction, except in cases where cooperation leads to parasitism. When a technological development shows strong social dynamism extra effort is needed to keep other actors besides theprimary actors involved in the process.

Of course the values and interests of all actors will in all cases heavily influence the possible interaction types and the degree to which they can be influenced.

Influencing the decision-making agenda

Especially in an uncertain and badly defined situation secondary actors may profit from cooperating with primary actors in the drawing-up of the decision-making agenda. Forming a triple alliance involving still more decision-arenas may in some situations be helpful.

It seems important for secondary actors that issues for debate are broad at the start of the discussions. This will enable secondary actors to contribute, but later on the issue will have to be narrowed down to those aspects that will play a role in the decision-taking.

Enhancement of expertise

When secondary actors seek to participate in a decision-making process their unequal information position should be counterbalanced as effectively as possible. One way in which secondary actors can gain the necessary expertise is by acquiring funds to elaborate and underpin their own views and to distribute the information that is generated in this way.

Expertise can be generated by the secondary actors themselves, as often happens in industry (trade unions), but also by external advisors (cf. the role of the Dutch science shops). Different types of expert seem to operate more profitably in different types of decision-making situation .

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SOME THOUGHTS FOR THE DISCUSSION ON DECISION MAKING WITHIN SCIENCE AND TECHNOLOGY: IS DEMOCRACY POSSIBLE?

Michael J. Moravcsik

The title could be interpreted in at least two ways. We can consider decision making within science, or decision making on broad issues which have some scientific ingredients. Much of the activity undertaken under the heading of "science and society" focuses on the second of these. Today, however, I want to concentrate entirely on issues of the first kind, that is, decision making within the confines of science itself. Such a constraint does not mean that we may not encounter "non-scientific" arguments playing a role also, but the object of the decision will be a strictly scientific issue.

In general, we can say that the decision concerning whether science should be performed and how much of it is nowadays made jointly by scientists and those sponsoring science, that is, private industry and the government. At the other end of the scale, the decision on what specific scientific problem be addressed and how is, for the most part, a decision made by the scientists themselves. There is also an intermediate domain, the decision about what large fields of science should get how much attention, and decision in that is made in an intermediate way, that is predominantly by the scientists but with some input by the sponsors. My focus now will be the ways in which scientists make their decisions, and problems that arise in this process.

We need to distinguish, for the purposes of our discussion, Little Science from Big Science. The former is the traditional format of scientific research, involving only a very few investigators working together (or even a lonely scientist working by himself), involving only small sums of money (say, at most $100,000-$200,000 per year), using equipment under the individual control of the investigator, taking a relatively short time (a few months or a year) to conclude a definite phase of the work, and providing, at the end of the period, a respectable set of data which can make a rather unambiguous and substantive contribution to the progress in the field. In contrast, Big Science is a style of doing research which involves teams of researchers possibly as large as 200 people, costing $10 or $20 million, utilizing central equipment which costs 10 or 100 times more than the experiment itself, extending over a time period that can amount to 5-10 years for a given phase, and which may yield, at the end of all this, data which are indecisive, fragmentary, and ambiguous, and which therefore contribute only a somewhat fuzzy but in any case tiny amount to progress in the field. Why Big Science is the way it is is something I will discuss below.

Decision making within Little Science, although not free of problems, is on the whole, fairly smooth and has turned out to be quite successful. Although there are various methods, for example, to make decisions about who should get resources for what work, in general the peer review, as applied to individual proposals, is the predominant way to proceed in basic research, and even in applied research a mechanism not too far from this prevails. Peer review works, to the extent that it does, because in Little Science the traditional scientific method, on which scientists have formed a consensus, operates well and can provide a fairly dispute-free and functional method for making decisions. To be sure, even in Little Science contemporaneous applications of the scientific method are not always decisive, and with some of the information not in yet, decisions cannot be made entirely based on the scientific methodology. On the whole, nevertheless, the traditional areas of science have been adjudicated by the scientific community itself well enough so that a large amount of progress has been made, and so that judgement by hindsight does not differ radically from the contemporaneous judgement exercised at the time.

This cannot be said for Big Science. The characteristics of Big Science listed earlier have grown out of an inevitable trend in science that places us increasingly closer to the limits of perceptibility of nature. Modern science started out with the study of phenomena within everyday human experience, and these phenomena could be observed directly by the human senses, without too much technological gadgetry. As this tiny domain of nature which is on a "human scale" was increasingly exhausted, science moved on to domains of nature increasingly farther from direct human perception and experience. These "faraway" domains are, of course, no less significant in the overall structure of nature than were the older ones close to human perception. Indeed, we could argue the opposite, namely that these new domains play a more fundamental role in natural laws than the old ones.

Nevertheless, in spite of the importance of these new domains, research of them becomes increasingly more difficult. The phenomena we want to study must be created "artificially" in our environment, and then signals from them must be laboriously and through a long chain of intermediaries translated into some other signal that we can perceive with our direct human senses. These factors are responsible for the huge cost, the centralized equipment, the gigantic research teams, the length of the experiments, and the indecisiveness of the final results. In addition, the theoretical interpretation of such results also becomes more difficult, not only because of the quality and character of the data, but also because the structure of the laws of nature in such distant domains may very well be increasingly incompatible with the functioning of the human brain.

The consequence of all this, and a crucial one for the purposes of our present discussion, is that the usual elements of the scientific method become degraded and blurred. The interplay of experiment and theory becomes weak and intermittent, because the data are few and can be provided only many years after a theory demanded them. In the intervening period theory does not enjoy the constraining influence of comparison with data, and hence false theories can thrive for a decade or two before they become implausible. Theoretical ideas, because of the dearth of new physical ideas, spring from pretty mathematical schemes, of which there are an infinite number, and hence the theories built on them without further fertilization from new physical insight are likely to be incorrect.

In such an environment, human elements of personality, oratorical power, interpersonal skills, etc. gain an unduly huge influence in the shaping of scientific research in these areas, and therefore the method used in these fields strays away to come very close to the much more subjective methods used in the social science and humanities. Yet, the final criteria of progress in science have not changed, it is only that the deteriorated methodology becomes incapable of serving it.

As I mentioned earlier, decision making within science in the Little Science fields is done, reasonably successfully, by the scientific community itself, and the decision making is credible on the outside of science, because the historically successful scientific method underlies the decision making process. This is no longer the case in Big Science. This is a new problem we need to face.

What can we do about it? Scientists specializing in other fields seldom have the expertise to make substantive judgements in the Big Science fields, and people altogether on the outside of science are in an even worse position in this respect. At the same time, those within the particular Big Science field being assessed have lost their moorings and their judgement has become dubious. Furthermore, such a big science community, partly because of the lack of true progress in the field, and partly because of the necessity of requesting huge resources from outside the scientific community, assumes a siege mentality, in which admission of any problems or of anything but complete success becomes a taboo.

It is clear then, that somehow the scientific community outside the Big Science speciality must enter the decision making. This is even more necessary since certain fields of Big Science can make such enormous demands on the resources available for science that gratifying them will inevitably have an adverse effect on the resources available for other science. Such a crisis erupted a few years ago in Britain in connection with that country's contribution to the international high energy physics laboratory, CERN. In terms of the language of democracy vs. autocratic governing, a broader basis for decision making becomes necessary partly to avoid concentration of benefits into the hands of a few, and partly to avoid bad decision detrimental for all.

In my view, the way to solve the dilemma is to focus the role of the "outsiders" in the decision making within a Big Science field not on making specific technical assessments, but on making sure that the traditional scientific method is used in drawing conclusions. A good scientist can tell even in a field other than his own if data are indecisive, if theories are conceptually ugly because of ad hoc elements, if theories are "slippery" in the sense of being added more and more adjustable parameters as the data become more and more stringent, whether theories pertain to the domain of data which is available or aim at domains outside the data where they are untestable, etc., etc. Experienced scientists can form their own judgement on whether or not, and whether a demanded piece of new equipment is really indispensable or whether other alternatives are available or even preferable.

As a very topical issue in such decision making, let us consider the so-called SSC issue, that is the question of whether the suggested giant particle accelerator called SSC, the building and operation of which would consume at least 5-10% of the funds used for basic scientific research in the United States, should be built or not. The issue has many dimensions (scientific need for the machine, its technological sophistication in view of new and projected development, its non-international status, etc.) which we do not have time to discuss here. What we are discussing here is the process whereby this decision is being made and should be made. To this very day there has not been a poll of the high energy physicist, of the physicists as a whole, or of the American scientists as to whether the machine is wanted or not. To be sure, the American Physical Society has no mechanism in its constitution or bylaws for ascertaining the views of its membership on such an issue. In my view, however, the government has been remiss in not requiring that such a poll be taken.

Instead, the initiation of the proposal was done by inducing the President of the United States to declare himself for the project first, after which a clever lottery scheme for the siting of the machine was set up, the result of which will not be available for many months. In the meantime, an attempt is being made to commit Congress, in spite of the burning need for economizing, to the expenditure of several billion dollars, in the hope that once enough money is sunk into the project, it can not be reversed, even if all the 49 losers of the siting lottery team up to oppose the project.

Democracy works only if the citizens watch carefully what it is exercised. This certainly holds also in the democracy within the sciences. The danger for a lapse in democracy is particularly acute in connection with decision making in Big Science. The conclusions of this, with regard to the SSC issue, are crystal clear.

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MACRO-STS: THE NEW FRONTIER?

Willem H. Vanderburg

Introduction

In order to reflect upon the state of the art in STS and carry out some intellectual stock-taking, it is useful to make a distinction between its macro- and micro-aspects. I will readily admit that these terms are anomalous -- at least in principle. After all, is STS not about as macro a level of analysis as possible in a modern society permeated by science and technology? Yet by introducing this distinction I am able to focus on an aspect of STS which, I will argue, must be strengthened. By micro-STS, I mean the study of the influence a specific technology or scientific undertaking has on human life, society and the natural environment. Macro-STS refers to another level of analysis which explores the overall effect of many scientific and technical undertakings. I will argue that these two aspects of STS are interdependent, the former providing a kind of situational holism, while the latter seeks a holism with a much broader scope.

As has been the case in other emerging fields of inquiry, there is an implicit assumption that if researchers accumulate large numbers of micro-level studies, eventually a macro-level framework will emerge. In the history of technology, for example, scores of detailed studies of the histories of specific technologies have not made it much easier to constitute a history of technology. This problem is now beginning to be recognized. We all appreciate that the whole is more than the sum of the parts and that the Gestalt of any detailed theoretical study is constituted against the implicit and explicit views of the broader context. This context can be formed either through the world-views and ideologies received from one's society or from careful critical studies.

To avoid any misunderstanding, let me point out that I am not saying that macro- and micro-STS do not now exist but that these levels do not sufficiently interact, and that this interaction is not now regarded as essential if a coherent inquiry is to emerge. If this were generally recognized, a new frontier in STS would be opened up -- which would in turn greatly strengthen the field.

In order to show how macro- and micro-STS can mutually benefit each other, I will consider some of the theoretical challenges involved in macro-STS. When considering the three complex systems involved in STS, namely science, technology and society, it is immediately clear that they do not each exist in their own space and time, interacting with each other across their external boundaries. They interpenetrate and are enfolded into each other.

I will mention three crucial aspects of this interpenetration that must be kept in mind later on. First, the three systems share constituent elements since scientists and technical experts are at the same time members of society. Second, because they are specialists they rely on the culture of society for images, conceptions and models of the larger wholes beyond their specialty, including science, technology and society. By culture (1) I mean the basis on which the members of a society interpret their experience and structure the

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relationships with each other and the world into a coherent way of life. Third, as technologies of scientific undertakings become embedded in the fabric of a society they are experienced, and consequently internalized into people's minds, thus contributing to the interpenetration of the systems of science, technology and society. This enfolding constitutes the retroactive effect of science and technology on human life and society. The human and social implications of the dynamics of the three systems constituting the STS ensemble will typically not show their true significance until the analysis reaches the level of culture and society. There are many other aspects of the interpenetration of the STS ensemble. I will bring some of these into focus by first examining science, technology and society separately.

Science

It is a commonplace to assert the exponential growth of scientific knowledge. This leads to the assumption that science evolves an ever more elaborate and detailed map of the world we live in, making possible an endless human and social development. What is not sufficiently appreciated in this proposition is the fact that scientific knowledge is of a *specific kind*. Hence, when its development is to the detriment of other kinds of knowledge it produces ignorance as well. In other words, I am arguing that the contribution of science to the STS ensemble is both a growing knowledge of reality of one kind and a growth of ignorance of another. This is greatly accentuated when the culture of society makes science *the only* path to reliable knowledge. The implied process of mystification causes society to lose track of the fact that science, like all human inventions, has its limits -- being useful for some things and useless for others. Thus, to examine the influence of a specific science or the whole of science, macro-STS must be included. I will explain this in some detail.

Although the so-called industrially advanced societies are distinguishable from all other societies, past and present, in terms of the historically unprecedented interdependence and interpenetration of the human, societal and technical spheres, there continues to be an incomprehensible lack of interdependence between the social sciences and humanities on the one hand, and the professional, applied sciences and engineering on the other. When I compare the daily-life "worlds" of the members of any modern society and the "worlds" of the various disciplines, it becomes clear that they vary greatly with regard to the way they see the role of science and technology. In the former, people experience and are bombarded with information about the fundamental and transforming roles science and technology have in our modern world, while in the latter we can find introductory and advanced textbooks in the social sciences and humanities where science and technology are hardly mentioned or appear to be peripheral phenomena (this already becomes evident when one consults the index).

The mirror image problem is also common. For example, engineering textbooks rarely refer to persons and society, and when they do, the theoretical and intellectual implications for the matters at hand tend to be insignificant. Yet most of the major challenges faced by individual societies and by humanity as a whole derive from the growing interpenetration of the human, societal, natural and technological spheres.

I would not state this well-known problem were it not that the theoretical implications are rarely drawn. The situation is just one manifestation of the fact that the findings of the different disciplines are not mere puzzle pieces that can be fitted together to constitute a coherent view of reality as it is known by a society. The difficulty of communicating across disciplinary, departmental and faculty boundaries within the university is rooted in the intellectual division of labour on which modern science is based. In part, this reflects the inadequacy of the mechanistic world-view, particularly for living wholes and their interrelations. Living wholes are never constituted from separate and independently existing parts the way non-living systems are. A living whole comes about by progressive internal differentiation through which "parts" are created. Something of the whole is present in each "part," so that the "part"-whole relationship is very different in a living whole from what it is in a non-living one. Actually, some physicists, like David Bohm(2) have suggested that this is true even of physical matter.

The same argument applies to society as a living system. Elsewhere, I have made a detailed study of the enfolded, non-mechanistic nature of a society and its implications.(3) I will therefore limit myself to a few details. Human beings do not experience the categories and divisions imposed on their world through scientific and technical specialization. A person's life is not lived in separate sectors with labels such as the scientific, technical, economic, social, political, legal, moral, religious and artistic. When we consider a particular action, these are dimensions of that action. Some of them may be more crucial than others, but all of them are enfolded into an action. The same is true for any institution or way of life of a society. There are no distinct social, economic, political and other subsystems. These are dimensions of a way of life individually and collectively lived in an enfolded manner.

A simple analogy to the problem may be drawn from the making of architectural and engineering drawings. Complex three-dimensional objects are represented in two-dimensional cross-sections and projections. These "specialized" views are carefully labeled in such a way as to indicate how together they describe the larger whole. This is not the case with the social, economic, political, legal, moral and religious "projections" of society made by the social sciences and humanities, and it is next to impossible to scientifically put these dimensions together.

In order to create a less fragmented knowledge base, scientific disciplines will have to collaborate to achieve a common base-map other than the mechanistic one used thus far. This map would be elaborated by each community of specialists in both general and specific features in an ongoing attempt to superimpose all of them. On the macro-level this approach would search for a consistent and coherent map of society and the world.

At present, a trade-off between breadth and depth in favour of the latter yields a scientific knowledge base where the rationality on the micro-level does not translate to the macro-level. Since our culture still largely assumes that science is the only reliable form of knowledge, science produces ignorance related to the interfaces between specialties and how their microworlds fit together to constitute macro-level understanding of larger wholes.

Science contributes to the growth of ignorance in another fundamental way. When the scientific knowledge base plays a decisive role in the evolution of the STS ensemble for what is usually referred to as "development," its fragmented character is transferred into human life, society and the natural environment, thereby weakening their integrity. This is evident in the emergence of what we call a mass society and in the threat to the eco-system. The more the STS ensemble evolves the more we become aware of the interrelated nature of the world; yet the scientific, intellectual division of labour remains largely unchallenged even though it does not account for the nature of this interrelatedness.

Another aspect of the production of ignorance results from the application of scientific knowledge. Any scientific or technical undertaking introduces something new into the world, creating new relationships and new interdependencies which never existed before, and about which we are ignorant until we study them. For example, the introduction of an estimated 500 to 1,000 new chemicals per year, whose effects on human life and the ecosystem can be tested in only limited ways, produces on the average more ignorance than understanding of their actual and potential effects. The only testing that takes place involves exposing laboratory animals to high dosages for relatively short periods of time. There are no tests for long-term, low-dosage exposure and, what is even more serious, there are no tests for the complex positive and negative synergistic effects that may occur. Since their overall effect on human beings in a given environment is a non-linear combination of the specific effects, nothing scientific can be said about their effect on human health and thus no genuinely effective overall standards of safety can be determined.

Similarly, the introduction of computers into many spheres of human activities creates an enormous ignorance of their effects, because they create new situations, new interactions, and new patterns and social structures which never existed before.

The growth of knowledge of one kind and ignorance of another requires a critical study of how modern science and the intellectual division of labour have been and to a considerable degree continue to be guided by a mechanistic world-view. To put it somewhat simplistically, each community of specialists is assigned one piece of the societal and universe "machines" so that the information they gather can be totalled up in a comprehensive understanding. In the course of this development, machines became more complex. The first generation of mechanistic world-views based on the clock has made way for a second generation based on the computer, servo-mechanisms, feedback, and information theory. Furthermore, as the number of relationships and constituents in the universe and society became more complex and diverse, it was gradually realized that the whole is more than the sum of the parts. There were limits to reductionism, and gradually the universe became conceptualized in terms of a complex network or system composed of many other systems. Despite all these refinements, the knowledge base produced by the intellectual division of labour has properties that would appear to violate the mechanistic assumptions about the "nature" of the universe. The "confusion of tongues" between disciplines should not have occurred if the universe was truly mechanistic in character. Furthermore, the objectivity and rationality on the micro-level should have translated to the macro-level. I believe that the discrepancy between what we actually found and what we expected to find is creating a major theoretical challenge for our age. Given the growing use of the scientific knowledge base, both within any given society and around the world, any limitations of this knowledge base are bound to have profound consequences for the future. STS, therefore, has an important role to play.

What I have suggested about some aspects of the role of science in society has important implications for what Kuhn has called a paradigm or disciplinary matrix. It is not a neutral symbolic medium through which a community observes and acts on the world. Rather a paradigm is a filter through which a relatively coherent microworld is derived from a complex interrelated reality, by means of explicit as well as hidden assumptions and myths. Through connecting macro- and micro-level studies of the modern scientific knowledge base, STS can analyze some of the properties of these filters and discover why they produce relative, isolated islands of knowledge while extending the sea of ignorance around them. Science is a study of reality with minimal reference to context. STS might on the basis of the suggested analysis develop ways in which specialization can be given a context as the ground against which specialties are configured. It is not a simple task, however, to change an intellectual tradition shaped for centuries by the myths of a mechanistic world-view.

If STS is not to contribute to the problems outlined above, it must be based on at least two distinct but interdependent modes of knowing. The first derives from frontier research of the kind customarily encountered in any modern scientific and technical discipline. This approach produces an ever-greater level of specialization, trading off breadth for depth. Questions of context and broader interrelationships thus play, at best, a minor role.

Frontier research must be complemented by contextualizing research, where breadth is emphasized over depth, including the integration of the findings of frontier research by contextualizing them in relation to each other and their human, social and environmental significance. In so doing, other aspects, implications and significance will be unveiled which may complement, negate or challenge some of the findings of frontier research. Hence, the two levels of analysis are in dialectical tension with one another. Each one has consequences and implications for the other. If STS involves both components, it makes a vital contribution to the university, where frontier research and teaching are the dominant modes of advancing and transmitting knowledge.

Technology and Technique

Technology, like science, makes a unique contribution to the STS ensemble. Once again, we find a "confusion of tongues" between specialists. Donald Schon(4) has illustrated the problem by showing that when different experts examine the challenges faced by a Third World village, they tend to emphasize the factors falling within their own domain of expertise as primary, arriving at incompatible and non-complementary diagnoses. The many factors of the situation are arranged by each expert into different Gestalts. The significance of this kind of problem becomes fully apparent only by means of a macro-level analysis.

What sets modern societies apart from all others is the decline of the role of culture. A wide range of activities is no longer based on custom and tradition grounded in a culture, but on the findings of research. These societies research virtually every sphere of human activities in order to render them more efficient, rational cost-effective or to eliminate certain problems by taking a scientific approach. They do this on the assumption (and this is one of the cultural hypotheses or myths in the anthropological sense) that the quality of life can be improved by rendering the means of our existence more efficient. This research typically comprises four stages.

The first stage comprises the study of some area of human life for a particular purpose. The results of the study are used in the next stage to build some kind of model which can range from a precise mathematical theory to one that is largely qualitative. In a third stage, the model is examined to determine what happens when its parameters are altered in order to discover when it functions optimally. A technical intervention follows to reorganize the area of human life studied originally to achieve the highest efficiency and rationality demonstrated possible by the model. It is by means of this pattern of events that modern societies seek to improve the productivity of a plant, the running of a large office or hospital, the effectiveness of classroom instruction, the performance of a professional athlete or hockey team, the functioning of a group, and even the satisfaction derived from a sexual relationship. The result is a vast constellation of techniques associated with the natural, biological and social sciences.

Increasingly, modern societies are not so much characterized by their industrial and machine-related technologies as by the fact that almost every aspect of these societies is organized and reorganized on the basis of a variety of techniques, which together constitute a technical way of life ensuring that everything is done as efficiently as possible. Once again, it is on the macro-level where the inherent difficulties become most apparent.

Whatever is affected by a technical intervention is separated from its social and natural contexts. It is then improved on the basis of criteria which make little or no reference to the way it fitted into and will fit into these environments. Efficiency, cost-effectiveness or cost-benefit measures are all ratios which compare outputs with inputs to internally optimize some activity or process without any reference as to how these improvements will fit into the socio-cultural matrix of a society or into the ecosystem (this came as a recent afterthought in the form of techniques such as technology and environmental assessment). The same problem occurs to varying degrees in the rational allocation of scarce resources by a variety of techniques. The technical way of life therefore produces tensions within the fabric of a society as well as straining the balance found within the ecosystem.

The technical way of life is in sharp contrast to the "rationality" of traditional societies based on custom and tradition, which embodied values that could adapt any part of the socio-cultural matrix to new circumstances without losing sight of the integrity of the whole. We will have to find other ways of accomplishing this. The technical way of life best described by Jacques Ellul(5) is characterized by a lack of reference to context, thus producing a loss of harmony, coexistence, compatibility and coherence in the social and natural fabric. Our mechanistic world-view and heritage considered this context of little relevance. The currently predominant second generation of mechanistic world-views, based on cybernetics, systems thinking and information technology, are, when applied to the human and social spheres, a search for the living among the dead.

The technical way of life is characterized by a growing rationality of the micro-level, which is undercut by enormous problems on the macro-level. We are clearly seeing this in the application of science and technology to defence. We have now arrived at a situation where the deployment of the so-called defense systems could destroy life on this planet. The benefits of many new chemicals are increasingly undermined by the serious contamination of the ecosystem and the threat this poses to human health. The benefits of an increased efficiency and productivity in the manufacturing and service sectors of the economy is expected to be increasingly undercut by making a portion of the population unable to participate in society.

It is more and more difficult for individuals participating in a growing number of rationalized and technicized relationships controlled and organized by experts not to become spectators to much of their own lives. To maintain a certain integrity of being in the many roles they must play in a highly fragmented society is an enormous burden. The reduction of meaning, a sense of reification and alienation, makes individuals less able and gives them less energy for meeting the challenges that lie ahead.

I am not arguing that we abandon the values of rationality, efficiency, productivity and cost-effectiveness, but rather that we complement them by values related to compatibility with the larger context. This will require a different approach to scientific and technical education, and an adaptation of the structure of the modern university to these needs.

Thus far I have argued that the development of science and technology in the West, based on the hypothesis of a mechanistic universe, has not yielded the kind of results anticipated by these assumptions. The fragmented character of the scientific and technical knowledge base, the "confusion of tongues" between specialists, and the struggle for the integrity of human life, society and the natural environment would not have occurred in the way they have, had the universe been fundamentally mechanistic. Each of the scientific and technical specialties have become somewhat like sub-cultures each living "in their own micro-worlds", which do not depend on and give ready access to the micro-worlds of other specialties in order to give ready access to the whole.

Society

Much of what I have argued above has repercussions on society. Within the scope of this overview, I can touch on only a few implications. The effect of rationalization and technicization resulting from the technical operation separates the knowers from the doers and externalizes control from execution. As a result, when the density of technicized relationships in human life increases, the individual cannot fully participate in these relationships and becomes a spectator to a significant portion of his or her existence. Thus the rationalization and technicization of human life reifies individual and collective life.

Incidentally, the above again illustrates the essential complementary relationship between micro- and macro-STS. What in relation to any one given technique or scientific undertaking might be a minor side-effect could constitute a major phenomenon, when the similar effects resulting from the kinds of patterns in science and technique that were identified earlier in this paper combine in a positive or negative synergistic way. Thus, the analysis of the effects of one technique at a time cannot possibly reveal many significant aspects unless they are placed in the broad context of macro-STS. This is why cost-benefit and risk-benefit analyses fail to identify some of the most fundamental human and social consequences of science and technique. The integrity of individual and collective life contributes to coherent patterns of evolution, frequently causing a culture to produce very similar side-effects in different spheres of human activity. Hence the above example is not an isolated one.

The characteristic patterns of scientific and technical development identified earlier have other important effects on society. I will give another example. Elsewhere(6) I have shown that the patterning of internalized experiences, constitutive of the mind, builds a metaconscious structure of experience by processes that go beyond individual experiences, and that it implies the values and myths of a culture. Communities create myths by absolutizing reality as it is known to them. Briefly put, myths are created when these patterns are extrapolated across the unknown to reality itself. Reality is implicitly assumed to have the same Gestalt as reality as it is known by a culture. Hence the unknown is no longer a threatening source of potential disorder but simply a reservoir of missing bits and pieces that, once discovered, can be added to reality as it is known. These assumptions are never made explicitly in the history of a society. They are matters of what is so self-evident and so obvious that it is inconceivable that things could be fundamentally different. Centuries later observers may wonder why no one saw through the myths that structured the way of life of a culture.

This process of absolutization is accompanied by one of sacralization because of the following dilemma. During each epoch in its historical development a society is generally placed before one or more related phenomena, which so permeate it that its very existence and thus the lives of its members also become inconceivable without them. For the prehistoric group such a phenomenon was nature, and for the societies that began to constitute themselves at the dawn of history it became society itself. The patterning of experiences in the mind identifies such phenomena in a metaconscious way (i.e. the patterns transcend individual experiences). This places a community before a dilemma. It could decide that such a phenomenon is so all-determining that the community has little or no control in the face of this fate. On the other hand, and this is in fact what happens, it could sacralize the phenomenon by metaconsciously bestowing an ultimate value on it. Necessity is thus transformed into the good, and the social order based on it is the expression of the community's members freely striving for that good. The freedom and cultural vitality thus metaconsciously created eventually permit the sacred to be transcended as an all-determining force, and make human history possible. At the dawn of history natural determinisms were slowly transcended, although social ones eventually took their place. The bestowing of an ultimate value on that which is most central in determining the life of a community metaconsciously orders all other values implied in the structure of experience of its members. Thus, this religious operation creates a sacred, a system of myths and a hierarchy of values, which together constitute the basis for cultural unity.

Today the system of all techniques not only largely constitutes our milieu but also structures many human relationships, social networks and institutions. The secular religious attitudes our society creates towards its most constitutive and central phenomena, namely the nation-state and the system of techniques, requires that culture be included in the core of STS studies.

Observers who recognize themselves as members of a culture having acquired its symbolic apparatus for interpreting and acting on reality will approach STS in a different manner from those who do not. Membership in a cultural community requires a critical awareness and attitude toward the cultural-symbolic basis of one's own existence rooted in a cultural community, its knowledge base and its way of life. The illusion that our modern society is secular has given up a map which has veiled the possibility of a secular sacred and religious attitudes to that which most centrally determines a way of life based on science and technique. Recognizing a need for a measure of iconoclasm, the modern observer of science and technique places the roles these play in the broadest cultural context. To an observer who does not recognize the religious attitudes that have sprung up around science and technique as central and determining phenomena of modern culture, any iconoclastic activities introduced in the analysis of science and technique appear inappropriate, foreign and unscientific. Terms such as "optimist" and "pessimist" often reflect fundamentally different secular religious commitments, and the emotional energies which these terms symbolize in the absence of any real analytical and academic content shows how profoundly our lives are influenced by a way of life dependent on science and technique. The present intellectual division of labour makes specialists dependent on and sensitive to daily life knowledge of science and technology. It is therefore essential to critically analyse the cultural roots on which any specialty is built, first during higher education and later through professional practice. Such an analysis must be an integral part of STS.

Evolution of the STS Ensemble

The knowledge base a society has of the roles science and technology play within it and, more importantly, the extent to which a particular individual has internalized the knowledge, either indirectly through formal learning or directly through experience, shapes the exercise of individual and collective responsibility. We all know from experience that when you lose control over the direction of a car, the steering corrections you make on an icy road tend to be exactly the opposite from those you would make on a dry pavement. In the same vein, the direction of STS studies and that of the modern university as a whole may appear almost opposite to each other, depending on the degree to which an observer contextualizes his or her vantage point and observations. To clarify this, I propose to pursue the car analogy.

Without getting into the details, we may regard a modern society as a hypercomplex cultural entity capable of addressing challenges and deciding between options by means of its values and political institutions. The most common strategy the members of a society pursue when facing a problem or choosing between options is to creatively extend their customs, laws, institutions, technology, morality or religion in a cumulative fashion. That is, in coping with daily affairs a society tends to extend its culture and way of life. This makes a great deal of sense because these efforts lead to a strengthening of the social order. This is particularly true when a society has embarked on a new epoch in its history and is building a new way of life.

After a certain time, however, this initially successful approach may begin to have some of the opposite effects. The reasons for this reversal are not difficult to grasp. A growing number of problems a society faces will be directly or indirectly related to the limitations of its culture and way of life, partly resulting from the assumptions it has implicitly made about the nature of the universe and human life within it, past, present, and future, and the accompanying process of sacralization. At this point, attempting to solve the problems by doing more of the kinds of things that help produce these problems in the first place is obviously counterproductive. In other words, the same kind of action can in one context be a genuine solution (thus producing some kind of negative feedback) while in another situation it may be counterproductive (producing some sort of positive feedback). The situation is not unlike that of the car except that it is, of course, much more difficult to decide what phase of its development a society is in.

Societies generally have so much inertia that the passing into a situation of losing control is barely noticed, least of all by its centres of power. This is especially true when the culture and social order of a society have created a way of life that have brought some spectacular successes. There is then a tendency within a society to be blinded by this success and to almost indiscriminately, or at least less critically, cumulatively extend its way of life to an every greater diversity of situations and, through the retroaction of its culture on the human mind, to develop a religious reverence toward it.

The situation now makes open discussions more difficult because of their religious character. For example, those who think society is attempting to solve its problems by doing more of the kinds of things that help produce these problems in the first place may be greeted with "You want to back to the Dark Ages," or "If we don't do it, others will and we will lose out," or they may be branded as pessimists. The whole political spectrum tends to shift, and another age of believers and dangerous heretics looms up with all the potential for discrimination and violence. This tends to happen precisely at a point when society should encourage a healthy iconoclastic diversity of interpretations and adaptive strategies, each evolving in a climate of respectful dialogue and critique. After all, our symbolic relationship with reality is highly complex, and our stock of concepts by which we make our situation intelligible can, if it becomes inadequate, alienate us further from that reality. No one, regardless of political or religious position, is free from that risk.

Here we have in a nutshell what I believe to be the central rationale for one of the roles that the university might and should play in a modern society. A university should make some kind of negative feedback possible within the institutional framework of a society. This will not happen, however, unless the university maintains a critical distance with regard to what is happening in its environment, including a certain iconoclasm toward the religious attitudes that tend to crystallize around the phenomena on which a society bestows very high values. However, the prospects of this occurring under current conditions are non-existent.

In other words, the university as an institution should help create a point of reference determined as little as possible by the developmental processes in a society. Think, for example, of what would happen if your furnace could affect the set point of your thermostat, or if, when attempting to estimate the speed of your train, you were not able to look outside. The very nature of a culture and the way it shapes the minds of the members of a society makes the creation of such a point of reference very difficult, if not impossible.

If the university would maintain a critical distance and an iconoclastic attitude it could strive toward the institutionalization of a point of reference, provided it does not erode its autonomy by trading short-term benefits for the vital service it can render a society through its autonomy. I wish to be very clear on this point. I am not arguing against university-industry or university-government collaboration, but against a specific kind of collaboration which is not intellectually critical and iconoclastic. It is clear that in a modern society dominated by science and technology, STS research and teaching efforts within the university should be central in helping to determine its future course.

It is not my purpose here to defend a particular interpretation of the patterns of development underlying the so-called industrially advanced nations. I am suggesting that macro-STS should include the asking of some basic questions, such as: What are the fundamental patterns of development underlying the so-called industrially advanced nations? What roles do science and technology play in these societies and how do they contribute to their patterns of development? How are the main challenges facing these societies related to their patterns of development? Do these challenges themselves form a pattern, and if so, how do their nature and structure relate to the patterns of development of these societies? Can these challenges be overcome by cumulatively extending the patterns of development, or will this generally result in "doing more of the kinds of things that help produce these problems in the first place?" Is it possible to develop criteria by means of which alternate options can be evaluated according to the degree of negative and positive feedback they will contribute? Is it possible for what appears to be a genuine solution to a problem on one level of analysis to be a technological fix on another? The answering of these questions requires a macro-level study of science and technique in their broad context.

Macro-STS can contribute to developing an iconoclastic attitude toward myths which have served their function and open up new avenues of creativity and imagination to get around the situation expressed by an unknown author as follows: *If your only tool is a hammer, all your problems look like nails.* This is precisely the situation created by a secular religious attitude toward a phenomenon which, like anything else in human life, has its proper place, but which when it is sacralized becomes a god unable to deliver either democracy or socialism from its current dilemmas. Western civilization, in which the Jewish and Christian traditions have played such an important role, should not forget the risks of creating idols even when they are secular in nature.

Conclusion

The macro-level characteristics of science, technique and society outlined above together illuminate a fundamental pattern of evolution of the STS ensemble. In each system, the micro-level strengths and undeniable benefits do not translate to the macro-level. Because of the integrity of human life, society and the natural environment, however, this leads to some of the most fundamental challenges faced by humanity. It is in this area where macro-STS can make an essential and decisive contribution. Specialized knowing with minimal context, a technical way of life based on contextless rationality and values, and a society which, through secular religious attitudes toward science and technique, transforms them into the only true way of knowing and doing -- all these contribute to a prescription for trouble. To write this analysis and conclusion off as too pessimistic is precisely one of these anxiety-reducing reactions that adds to the seriousness of the situation.

Presently we seem to be in a situation somewhat similar to the one that occurred prior to the end of the Middle Ages.(7) The Church claimed that its knowledge was the only true knowledge, and the role of its experts (priests and theologians) in society increasingly produced results that on the grassroot level became incomprehensible. People began to search for new ways of living together, for finding meaning for their lives and for revitalizing their communities. Slowly a new historical epoch emerged, permitting Western civilization to unfold new possibilities.

Today again claims that scientific and technical knowing and doing are the one true way to a heaven reached by development, and that we must have a blind faith in the specialists and experts of the state and other large institutions, veil a reality that has largely been stripped of context and hence is unable to respect and support the integrity of individual and collective life and that of the natural environment. What will all our scientific and technical power gain us if we reify our being? Macro-STS must expose the limitations of scientific and technical activities to direct us toward a civilization which includes science and technology, but whose culture is not permeated by it, so that independent bench-marks and values can be used to guide them for human purposes.

I am not, of course, suggesting that STS studies line up in the direction I have suggested. On the contrary, the health of the field will depend on the emergence of various schools taking different positions. Questions like the ones I have raised should be extensively debated in STS studies, and I would expect that different answers to them will help constitute competing schools of thought. I believe this to be essential in the study of phenomena which so profoundly shape our present existence and which may put an end to that existence. At present, however, the level of analysis I have called macro-STS does not sufficiently interact with other levels of analysis, and I hope this article may make a small contribution to changing this situation.

Footnotes

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CULTURAL PARADIGMS AND TECHNOLOGICAL LITERACY

Paul W. DeVore

Those who have been concerned with the issue of cultural and technological literacy are aware of the multifaceted nature of the topic. There are many views of what constitutes technological literacy and considerable confusion and conflict. The probable reason for this confusion is the context within which discussions of technological literacy have taken place. Seldom do those who propose a given content base from which technological literacy is to be derived provide the context in which individuals are to function. The paradigm is assumed to be known. But the cultural paradigm has been evolving, and confusion and disagreement result from the differences in our cultural paradigms or world views. The purpose of this paper is to explore the relation of cultural paradigms to technological literacy in a changing world.

The World Today

The context in which the people of the world find themselves in the latter part of the 20th century is far different than the world inherited from their parents. For the most part nations and their citizens are no longer isolated. We live in an interdependent, ever-changing world of accelerating industrialization, continuing population growth, widespread malnutrition, increasing depletion of non-renewable mineral and energy resources, and serious questions about the quality of the life-giving and life-sustaining environment.

Technological and social change have been constants in the civilization process. The difference today is in the pace and magnitude of the changes. For example, in less than 80 years the United States has changed from a way of life primarily based on agriculture to a society based increasingly on new communication and information systems. Today, primary heavy industries are located throughout the world. Nations other than the United States and selected Western European countries produce world quality products in computers, machine tools, construction equipment, automobiles, textiles, electronics and home appliances. The fusing together of the technical means of the computer and that of communication systems has given birth to the creation of information systems and intelligent automation that have altered, and will continue to alter, the nature of society and our perceptions of ourselves.

Within the next decade or so it is highly probable that a new form of technical means, biotechnology, will have societal impacts that are as great or greater than the computer and the transistor. The potential for altering the way we produce food, convert energy, provide health care, and produce materials is significant. So too will be the

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questions raised by the new forms of biotechnology with respect to value, error, and failure.

Human Factors and Technological Change

In earlier times most technical means could be understood by the average citizen. Control was vested mostly at the local level. Today, the increasing complexity of the technical means and the interlinking of multiple subsystems increases the potential of disfranchisement of more and more citizens.

New and more sophisticated technical means have increased the gap between technological growth and human understanding. The level of political and social understanding has also been affected and the inequality between the haves and the have-nots has increased. This increase in inequality has been in direct relation to the decrease in the ability of people to participate in and contribute to the creation, use, and management of the new technical means. This disfranchisement has direct and serious implications for the survival of democratic forms of government. Freedom is an issue of control. The disfranchisement of vast segments of population because of ignorance of the technical means that give shape and order to society poses serious questions and underscores a primary reason for pursuing the goal of a technologically literate citizenry in all cultures. A technologically *illiterate* citizenry will promote the demise of democracy and place in control an elite group of people who, by their knowledge and know-how, will control the technical systems and thereby the processes of public and private life nationally and internationally as well.

Adaequatio*

Eric Sevareid in a recent interview for Christian Science Monitor expressed his concerns about the problems of today. He cited three. He believes the three are new in history. "One is the leap into space. Another is the existence of ultimate weapons. And the third is the poisoning of the natural sources of life -- the rivers, air, food." He went on to point out that he doesn't believe that any of the real problems will be solved in outer space. "I think," he said, "they're solved in inner space and inner man, on terra firma" (Kidder, p. 6). The real problems it seems are with our knowledge, attitudes and values about self, others, our technological society and our life-giving and life-sustaining environment. Short of abandoning the Earth, we must address our present and future here on Earth. To do so we must attain "adaequatio" and become adequate to the task.

"Adaequatio," considered in the context of a democratic technological society, has unique meaning and provides insight and guidance in discussions about the technological literacy of citizens. The meaning becomes clearer if the discussion is in the context of participatory democracy, for it becomes evident that it is not possible for citizens to participate in a meaningful way unless they are adequate in their knowledge, comprehension, and understanding of technical means. "We cannot know and understand unless we are adequate to that which is to be known" (Schumacher, p. 39). "Adaequatio" is what enables us to know and comprehend anything at all about the world, our society, ourselves, and our technical means.

There has been a developing awareness that adaequatio is lacking among people throughout the world; that the choices we have been making, individually and collectively, about our technical means have brought forth undesired consequences. The result has been an evolving concern about intelligent and responsible citizenship, about ethics, and about the nature of technological choices and their impact on people, the environment and the future of the living Earth. This seems to be the context within which the issue of technological literacy must be addressed, a context which differs from many prevailing approaches.

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* From E.F. Schumacher, A Guide for the Perplexed, chapters 4 and 5.

Conceptual Frameworks

Current Contexts

There are several contexts in which discussions about technological literacy can be placed. These include those that are of concern to the corporate-industrial community, those concerning the individual as a citizen in a democracy, those concerned with the design of livable and sustainable communities and those that include the needs of "Gaia", the living Earth. The basic question is: technological literacy for whom, and why?

Exploring cultural paradigms is a necessary prerequisite to fruitful and productive research on technological literacy. Basic questions such as "What should all citizens know about and be able to do in the technologies?" are unanswerable unless the cultural paradigm is understood. Knowledge of the cultural paradigm in which technological literacy is to be grounded gives direction to discussion and research about technological literacy.

Paradigms

A person's beliefs and values direct his or her behavior. Taken as a whole the belief and value system describes a person's world view or paradigm. A paradigm can also be described as a set of rules and procedures under which people study, investigate, and pursue the subject matter of a given field of study or discipline. When the practitioners of a given discipline or field of study subscribe to a definition, then that definition represents a consensus and describes the paradigm (Pepper, p. 239).

Paradigms past and present

There are many paradigms from which people operate on a day-to-day basis. Some are examined paradigms. Others are unexamined.

Some paradigms have been well documented in the literature and have acquired identities with names such as capitalism, socialism, communism, monarchism, colonialism, catholicism, protestantism, buddhism, marxism, creationism, and scientism, among others. Other world views have resulted from the nature of the technological order of the society. Darcy Ribiero, in his classic work, *The Civilizational Process*, provides insight into the civilization process by identifying primary societal formations which reflect the cultural paradigm of the time. Examples include theocratic irrigation, mercantile slavistic, capitalistic mercantile, and imperialistic industrial, among others.

Historically, the collapse of civilizations has related to an incompatibility between the predominating mode of behavior and the evolving social or environmental context. When a large number of people within a society become aware of the seriousness of the problems, efforts are made to seek alternative social and technological solutions. The new direction is guided by the values and beliefs of an alternative cultural paradigm. When this occurs, large-scale social and technological changes take place.

The emergence of a new paradigm is generally accompanied by significant increases in the physical and intellectual energies of people. This was true during the late 1700s when the people of the world witnessed two significant social revolutions, the French and the American, and one technological, the industrial revolution in England. These paradigm shifts set into motion global changes that are still affecting the actions of citizens throughout the world.

The promises of the technological way of life have been a part of the vision of the future for many years. The vision of the future of most people has been one of continuous growth and the expansion of technical systems. The tenet of the prevailing cultural paradigm that has guided this thinking is that continual development and cumulative growth will solve the ills of humanity. Warning signals the last 40 years or so have made us aware that all is not well with the system. These warnings emerged even though it was apparent that the technical systems being questioned had also contributed to the improvement of the material quality of life, particularly in the Western world. However, as the systems became ubiquitous and larger, evidence emerged that these systems contained detrimental and destructive elements. The more significant of the early warnings concerned energy conversion and use; nutrition and health; food production and distribution; land use policies; population increases; loss of arable land through destructive agricultural and resource management practices; and the increasing deterioration of the Earth's biological systems. Collectively, these problems helped lead to the realization that humans, by their choice and use of technical means, play a critical role in determining the quality and sustainability of all life on Earth.

Over the last several decades evidence has begun to mount that not only is the life supporting natural environment being altered by human actions -- with possible serious consequences such as increased CO_2 levels, air pollution, deforestation, overgrazing, desertification, soil erosion, flooding, chemical spills, toxic wastes, and ground water pollution and aquifer depletion -- but also the social environment has become increasingly incompatible to humans and their needs and desires. Where people once considered the present to be stable, they found their lives being altered on an almost daily basis by forces beyond their control.

A New Awareness

A realization of how complex and interrelated the natural and created worlds really are emerged from a shaken faith in the potential of current technical systems to meet the needs of humans and be compatible with the natural environment. A new perspective and a new ethic have been evolving from an increasing awareness that the Earth is not large enough nor the resources plentiful enough to tolerate, for any long-term future, the escalation of the current anthropocentric and aggressive technical behavior on the part of humans. The new reality is one that recognizes the need for new global patterns of cooperation as well as the establishment of new relations among people and between humans, their technical systems and the natural environment. This new awareness places into context the question of education for the citizens of the world, namely, the question of knowledge and understanding of the relation of technical means to biological and social systems and the behavior of the Earth as a total living system.

What direction should be pursued if corrective action is to be taken? There are two options, one social and one biological. The social focuses on the organization of society and the creation of technical systems that contribute toward agreed-upon social purposes such as full employment, an enhanced quality-of-life for all people of all ages, and long-term sustainability. The second, biological, focuses on the creation of technical systems based on biological design and operating principles that contribute to the well being of all people and the sustainability of the social order and the living Earth.

Sustainability

An alternative cultural paradigm seems to be evolving, one that is being influenced significantly by the question of sustainability. The predominant world view in the West is based on a technocratic, industrial-scientific, or industrial-capatalistic paradigm. Drengson notes that this dominant paradigm perceives of nature as a mechanistic system which can be understood via its simple components and their external relations. The belief is that nature should be controlled for the benefit of humans and that only minor adjustments are necessary in the system to protect the Earth's ecosystem from harm (Drengson, p. 63). When tested against the criteria of sustainability, this perception has been found to be lacking. The evidence is mounting of extensive, and at times irreversible, damage being done to the ecosystem that sustains and nourishes life. People are realizing there are limits; that it may be best if we slowed the process and reassessed our values and our social purpose. Given recent experience citizens are increasingly hesitant to agree to the introduction into the environment of new, exotic, and complex technical means. Concern is growing about the long-term effects of the design and evaluative criteria currently used in the selection of our technical means. Discussions are focused more and more on the design and development of technical means that are appropriate to the long-term well-being of all life on Earth. A shift is taking place from viewing life in an instrumental way to perceiving the intrinsic worth of all life.

An Evolving Paradigm

Many events contribute to consciousness raising. Small incremental changes take place as attempts are made to address the dysfunctions of the system brought about by the social and technological orders of the old paradigm. Hubbard notes that at first energy is directed to dampening the fluctuations and managing the crises. Efforts are made to "return" to a prior condition, social order, or way of life (Hubbard, p. 37).

Ultimately the problems of the established social and technological order become unsolvable. Attempts at patchwork reform do not work. Only a shift in the basic operating model provides solutions that will enable a society to survive and perhaps evolve to a higher order. The late E.F. Schumacher believed that industrial society had reached its limits, that it was not possible to continue into the future using the industrial model. He asked: "Why should industrial society fail?" His answer was that it: (1) has disrupted organic relationships; (2) is rapidly depleting the earth's nonrenewable resources or scarce minerals -- mainly fuels and metals; (3) is degrading the moral and intellectual qualities while further developing a highly complicated way of life; and (4) that it breeds violence -- a violence against nature that at any moment can turn into violence against one's fellow men (Schumacher, pp. 35-36).

The dysfunctions of the present are the direct result of the technical means created and the inappropriate use of technical means. To make a transition to a society that is more sustainable will require the creation of alternative technologies. This will require a change in the perception of the role of technical means in society. Also required is a shift in perception about the purpose of life on Earth. Such a shift has been occurring and has been bringing about changes in the dominant world view of industrial societies. Examinations of purpose have focused on the core values of industrialism which emphasize materialism, economic growth, and an anthropocentric view of the Earth and other life. Drengson, in his examination of the shift away from the current dominant paradigm, notes that the evolving paradigm focuses on the "quality of life and a heightened awareness of the importance of environmental quality" (Drengson, p. 4).

This reconceptualization of our world view has been influenced by the contributions of many concerned individuals. The realization that the mechanistic world view and the fragmented reductionist Cartesian-Newtonian perspective, which proposed that the world and humans could be understood as mechanical systems composed of separate parts, may be in gross error provided the base from which the new paradigm began to emerge. The work of James E. Lovelock and Dr. Lynn Margulis in the 1960s made a significant contribution to the evolving paradigm. Their work provided a base for establishing an alternative view of the Earth, a view of the Earth as a living, self-regulating system. They called this perspective the GAIA hypothesis. This perspective calls into question the mechanistic, compartmentalized view of the world.

Emerging from the new awareness, new knowledge and concerns has been the concept of bioregionalism. Bioregionalism is a grass-roots movement concerned with social and ecological sustainability. It is part of the emerging paradigm. As the prefix "bio" implies, the focus is on life, all life, and the living Earth. A bioregion is, according to Kirkpatrick Sale, a life-territory, a place defined by its life forms, its topography and its biota, rather than by human dictates; a region governed by nature, not legislature (Sale, p. 43).

We find, on examination, that the primary factors bringing about a change to a new paradigm are: the realization of the cumulative dysfunctions of the dominant world view of industrial capitalism; the concern for the long-term effects of the policies of this world view on the quality of life of humans; the growing recognition that the quality of human life is not solely dependent on a higher level of material existence; the changing perception of the relation of human life to other life on Earth; the recognition that the Earth is a living system; and the emergence of the bioregional movement as a response to the challenge of creating and sustaining quality life on Earth.

Paradigm Characteristics

The dominant world view and the emerging world view differ in many ways. A review of the primary characteristics of these views will aid in later discussions on the implications for education and the preparation of technologically literate citizens.

The Dominant World View

The dominant world view, according to Drengson, is grounded in a scientific philosophy influenced by classical empiricism which aims to make science the philosophy and to divide fact from value. This approach is positivistic with an anthropocentric orientation toward nature. The goal is to attain a level of knowledge and understanding where prediction and control of events in nature are possible (Drengson, pp. 3-4).

Other characteristics of the dominant world view include: (1) a focus on continuous, cumulative growth, progress in scientific and technological knowledge and industrial production; (2) authoritarian operating characteristics; (3) the depersonalization of human interaction; (4) the promotion of government by technicians and specialists, corporate forms of association and a competitive approach to life; (5) the belief that nature has no intrinsic value, that the protection of the environment is necessary only when human life is involved; and (6) that cultural diversity is not an essential criterion (Drengson, Shifting Paradigms and Schumacher, Good Work).

The Evolving Paradigm

The world view of the evolving cultural paradigm consists of concerns which are grounded in ecology and the quality of human life.

Characteristics of the evolving world view include: (1) a focus on an ecologically feasible and sustainable society; the maximization of the possibilities for the development of the person; a stable ecosystem; the use of alternative, appropriate, and environmentally sympathetic technical means; (2) personal and community development in addition to economic development; (3) intrinsic values in activities, people, and objects, and an ecocentric rather than an anthropocentric relational perspective; (4) the design of appropriate and nonviolent technical means compatible with humans and their needs and the living Earth; (5) the goals of decentralization, regionalism, and small-scale, ecologically sound communities based on the conservation ethos, long-term perspectives, a regenerative biotechnology base, cooperativeness, diversity of life styles and technical means, and work as purposive and self-fulfilling; and (6) human perfection and development (Drengson; Maruyama; Pepper; and Sale).

The Meaning for Education

The emerging paradigm, embracing the Gaia hypothesis and ecocentrism, has many implications for education. The primary difference is in focus and goals. The challenge is to prepare citizens for living intelligently in an interdependent world on a living Earth. The knowledge base will be different from that required for the dominant world view. It will consist of knowledge about the living Earth and its bioregions, ourselves as self-aware human beings, and the design of appropriate technical means and sustainable communities. The foci of education for the future would be on bioregionalism within the relational perspective of ecocentrism. The process would be design oriented with ongoing evaluation focused on long-term sustainable futures. The perspective and process would be within the context of questions concerning the meaning of life and living. As living, conscious, thinking, and self-aware beings, with the capability of creating sustainable or non-systainable futures, it has become imperative that we accept the responsibility for the living future. To do so will require that we continually search for answers to the basic questions of all time. Who are we? Why are we here? Where are we going? How will we get there? Probing these questions will encourage discussion of controversial issues and the questioning of conventional wisdom.

Redirecting Technical Means

The redirection of technical means for social and ecological purposes will require a holistic focus. Such an effort will require the redirection of the purpose, content, structure, and processes of education. More attention will need to be given to human and social purpose in the context of ecocentrism and the design and development of appropriate technical and social means to attain collectively agreed upon goals. The design and education process will be guided by a new ethic, an ethic that transcends the uncontrolled, ad hoc, undisciplined approaches to the introduction of technical means in the past. The new ethic, grounded in the knowledge and value base of the emerging paradigm, is composed of five key sub-ethics. These are:

1. The humanistic ethic that directs individual and group actions toward the enhancement of human development and personal growth, not the technical enterprise.

2. The ecological ethic that recognizes the critical relation between the quality of human life and the living Earth.

3. The global ethic that directs attention to the understanding of human beings, social systems, technical systems, and the living Earth as part of one system.

4. The future ethic that recognizes the critical nature of human choices and their long-term impact on humans, society, and the life-giving and life-sustaining living Earth.

5. The enabling ethic that is grounded on the understanding that technological systems can be designed to be compatible with the living Earth and that the design and development of appropriate technical means will enable human beings to create more human and sustainable futures.

Technological Literacy

The last ethic, in context with the other four, directs attention to the fact that the evolving paradigm will require a type, level, and quality of technological literacy on the part of all citizens totally different from the literacy required by citizens in the dominant world view. It can be argued that the type and level of technological literacy required by the Industrial-scientific world view is limited and restricted when compared to the emerging world view. This is primarily because of the authoritarian, hierarchial, and specialized structure of the technical enterprise of the dominant view. The underlying principles of the evolving paradigm, however, require a high level of technological literacy as part of the basic education of all citizens. This is so because of the participatory nature implied in the evolving paradigm, together with the responsibility each citizen must accept for his or her own continual personal growth, together with the development of capabilities that strengthen the self-reliance and sufficiency of individuals and their communities.*

The New Literacy

The new literacy requires a new knowledge base incorporating the study of humankind; other cultures; technical and social systems and the behavior of these systems; processes of decision making; change processes; an understanding of the evolution of technical means; goals and values in human societies; the interrelation of systems and the behavior and control of systems both social and technical; the creative process in the design and development of energy systems, transportation systems, communication and information systems, and production systems; the process for designing and evaluating new technical means; and the design criteria for the selection and design of technical means compatible with bioregions and the living Earth. Examples of compatible design criteria re: (1) designing with nature where technical means and systems would be ecologically sound and the emphasis is on products made from reusable materials and designed for long-term use; (2) designing for diversity using a variety of technically appropriate systems as a means to contribute to the goal of long-term sustainability; (3) protecting the natural diversity of bioregions by creating technical means compatible with the ecology of the bioregions; and (4) striving for decentralization and independence of the technical systems and their component parts.

Human scale, diversity, and independence strengthen the potential for freedom and democracy and the sustainability of communities.

Conclusion

The future is being determined by choices made today by citizens throughout the world, individually and collectively. We are not well prepared to make decisions that are compatible with long-term sustainable futures. Our track record is flawed. The long-term projections for a future based on the current dominant world view are bleak. The evolving paradigm holds promise. Healthy communities in healthy bioregions on a healthy Earth are healthy for humans and all living creatures.

Our heritage has limited our choices and the time we have to act. The legacy of a living Earth with the potential of a quality life for all is attainable with the acceptance of the imperatives of the evolving paradigm, including the design of technical means that contribute to the building of sustainable, quality communities compatible with the living Earth. This places a new urgency and meaning on the mission of providing for all citizens education about technical means and human affairs.

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CORE CONCEPTS FOR SCIENCE AND TECHNOLOGY LITERACY

Robert E. Snow

INTRODUCTION: THE SYSTEM OF SCIENCE AND TECHNOLOGY

Historically science and technology have represented two very different aspects of human interaction with the natural world. At its core science embodies the desire to understand while technology is a product of the impulse to control. The modern vision of knowledge linked to power through the development of a science-based technology was first clearly articulated in the 17th century by Francis Bacon. But, with few exceptions, Bacon's dream remained unfulfilled until well into the 19th century when the development of the modern chemical and electrical industries initiated a new era. Since then the energies of western culture have been absorbed increasingly in two efforts of monumental importance. The first of these, the search for organizational forms designed to foster and exploit the potential of science-based technology, has been extraordinarily successful. Success in the second effort, the attempt to find ways of anticipating, responding, and coping with the increasingly rapid and widespread social and environmental consequences of accelerating technical change, has been much more difficult to achieve. The existence of rust belt cities, our inability to contain the nuclear arms race, the rapid growth of pollution in third world nations, and the emergence of transnational environmental problems, such as acid rain and the greenhouse effect, are typical examples of a large class of intractable problems which are connected in significant ways with the growing power of science-based technology.

If science is to play an appropriate role in a modern democratic society such as ours, we must develop a more subtle public understanding of not only its strengths and limitations, but also the ways in which scientific, technological, and social issues bear upon one another. And it must be a kind of understanding which will help us make sense of the many questions raised by the increasingly dominant role of science and technology in the modern world. We need to learn how to think carefully about questions such as:

> What can science and technology be like if highly qualified experts often disagree in their analysis of urgent problems related to environmental, health, or defense policy?
>
> How can these disagreements be resolved?
>
> What role should scientists and technologists play in public policy decisions and disputes?
>
> How should we understand the relationships linking science, technology and society?

The elements of such a perspective are briefly outlined on the following pages. In it science and technology are treated as systems of thought and action within which both sociological factors and a range of value laden decisions play central roles. For expository purposes, the system of science and the system of technology will be introduced separately and then some aspects of their interaction will be discussed. Two features of the material which follows should be noted. (1) To achieve a compact and provocative form of exposition, I have chosen to list a series of claims about science and technology. Because the broad area of science and technology studies is so diverse, I have arbitrarily limited the number of claims--ten for science and ten for technology--in order to force a degree of closure. It would be easy to add claims, but my goal is to find a minimum set of claims which will provide a coherent foundation for understanding the nature of science and technology and their role in a democratic society. (2) Rather than provide a lengthy text explaining the ways in which the various claims contribute to our understanding of science and technology, I have constructed two concept maps to serve as a visual explication of the claims.[1] In turn, the twenty claims help to explicate the two maps.

The System of Science

The view of science sketched below in claims S1-S10 suggests that our understanding of the role played by science and scientists in developing responsible public policy for an age of 'high technology' turns upon the answers to three basic questions:

1. What is the truth status of the claims of scientists? (S1-S4: Observation, Experiment, Theory)

2. How do research results become accepted scientific knowledge? (S5-S8: Sociological Factors)

3. What role do values play in scientific research? (S9-S10: Values)

Observation, Experiment, Theory

S1. Contrary to the popular image of science, theory precedes and informs observation. Otherwise, systematic observation and experimentation would be impossible. Therefore, observation is theory laden.[2]

S2. Because observation is fallible, mismatches between theory and observation are not easily or quickly resolved. If an experiment does not yield the anticipated results, the only conclusions which can be drawn are either the experimental technique was faulty and/or at least one member of the set of assumptions defining the experiment was mistaken.[3]

S3. Scientific knowledge is essentially underdetermined with respect to empirical evidence. This is because the generalizations of science (laws, theories, models, etc. always extend beyond empirical observations.[4]

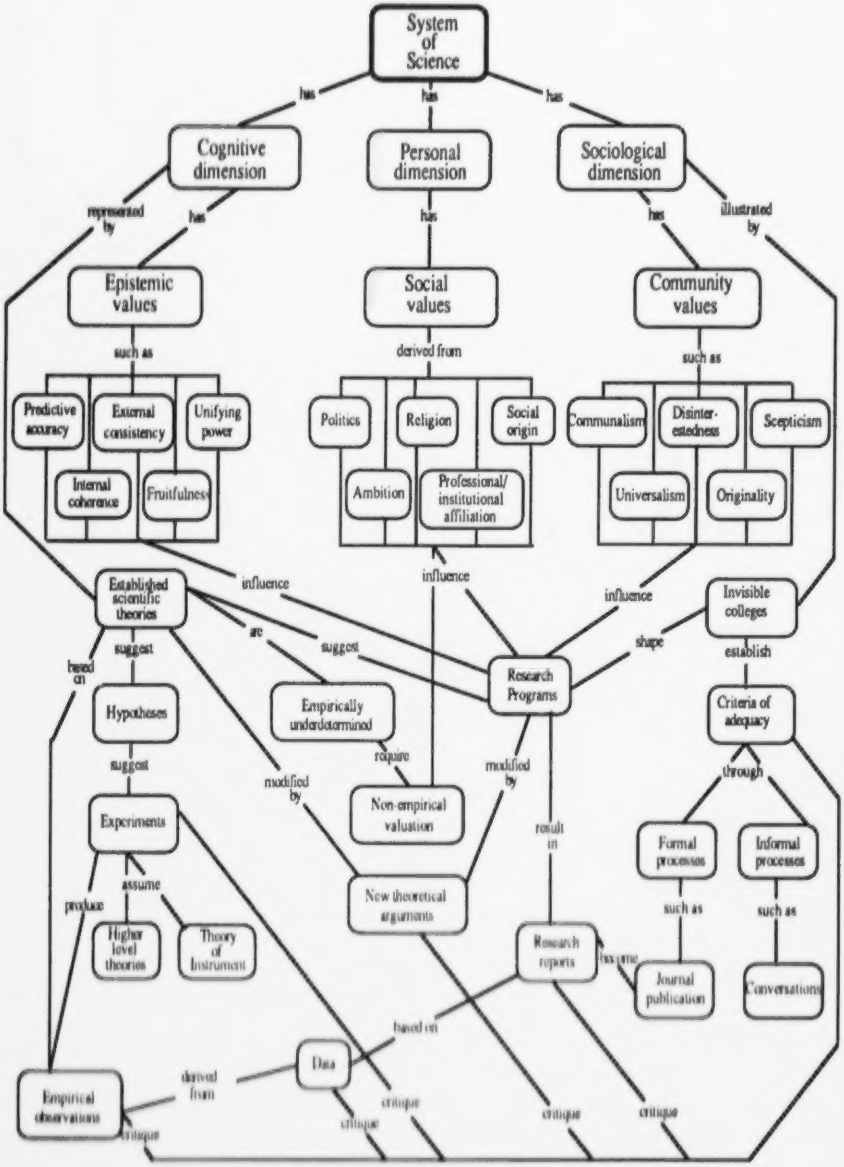
S4. Any body of empirical observations can be made to fit several different theories.

Sociological Factors

S5. Research scientists are extremely specialized because even in their major discipline (e.g. physics, chemistry, physiology, etc.) they are unable to consider more than a small fraction of the total amount of research reported each year.[5]

S6. Research scientists who share a common interest in a particular scientific problem or experimental technique form informal communication networks which have been called 'invisible colleges'.[6]

S7. Invisible colleges provide the setting where criteria used to assess the adequacy of many components of the research process are established and continuously modified. These criteria of adequacy are used by scientists to critique claims concerning experimental design, observational technique, data collection, and theoretical argument, etc. as the network of communication within an invisible college provides the arena within which scientific agreement is established and scientific disagreement is settled.[7]


System of Science
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Unifying power
Internal coherence
Fruitfulness
Politics
Religion
Social origin
Ambition
Professional/ institutional affiliation
Communalism
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S8. Public disputes involving science and technology (particularly disputes involving environmental, health, or weapons issues) are invariably multidisciplinary in scope. In the absence of a well developed invisible college devoted to the problem at issue, there is a substantial potential for a prolonged period of scientific disagreement.

Values

S9. Because values play a significant role in science and technology as well as within public policy, it is often impossible in the short run to distinguish unambiguously the scientific and technical issues from the policy issues.

S10. There are at least three major sets of values which play an essential role in shaping the content and the process of scientific research. Scientists from around the world are able to cooperate with one another because they share a common commitment to values such as honesty, skepticism, and originality.[8] A second set of values is incorporated in criteria such as predictive accuracy, internal coherence, unifying power and fruitfulness which scientists use in judging theories.[9] A third set of values is rooted in the personal and social commitments of individual scientists. As human beings with personal ambitions, with religious perspectives, with political commitments, with concerns reflecting their social origins, with professional/institutional affiliations in the academic or the industrial or the governmental worlds, scientists inevitably bring to their work a wide range of concerns which often help to shape the questions they choose to study and, at times, may incline them to favor one interpretation or experimental result over another.[10]

Claims S1-S10 sketch a view of science which departs significantly from standard popular accounts reflected in many K-12 science textbooks. Instead of emphasizing the value neutrality of science and the role of hypothesis, experiment and verification as the road to scientific understanding, this view claims:

1. At best, scientific knowledge is less than certain.

2. Research results are sifted, critiqued, modified, and revised in various ways through a sociological process managed primarily by colleagues who share similar scientific interests.

3. Values play a variety of essential roles in every stage of scientific research.

Within this revised view of science, experimental results continue to be of central importance in scientific argument. But the status of conclusions drawn from experiment are much more tentative and less decisive in settling scientific disagreements than the standard textbook account of science would suggest. This is especially true when the scientific claims are meant to play a role in the value-laden arena of public policy debate. There are a number of distinct, but related, reasons for this. For example, as S8 notes, public disputes involving science and technology often raise questions which seem to require the development of a new invisible college to establish the kind of social setting normally needed for the effective negotiation of scientific disagreement. Even given the existence of appropriate social mechanisms, it is a matter of sharp debate--particularly between sociologists and philosophers of science--whether the short term role of social values in shaping scientific discourse (see S9 above) can be neutralized in the long run as scientists continue the normal process of criticism and revision.[11] Finally, many public policy disputes depend in crucial ways on questions which seem to be scientific (what is the health risk associated with chronic exposure to low levels of various chemicals or what is the likelihood of a nuclear reactor core meltdown) but are extraordinarily difficult to research.[12] It is precisely when a topic is intrinsically difficult to investigate and is being considered in the context of a value-laden policy issue that social values are most likely to play a significant role in research. In such situations the best anyone can do is to look very carefully for evidence that social values are playing a significant role in shaping the scientific claims of contending experts and to recognize that often science can do no more than to modestly narrow the boundaries of uncertainty.

The System of Technology

One of the great strengths of modern technology is its ability to quickly develop new products and processes based upon the latest developments in science. But technology is not just applied science. In many respects it is a much more complex activity because the thrust of technology is action upon the world. It involves not only much sophisticated knowledge of how things work and the natural environment within which they work, but also a commitment to changing our interaction with the world. There are many different definitions of technology, none of them very satisfactory. Perhaps this is because of the many different ways in which technology touches our experience. In the case of technology, rather than seeking a better definition, it is more important to develop a habit of thought which encourages us to remember that whenever we think about 'technology', we should be thinking about artifacts, plus the knowledge embodied by those artifacts, plus the socio-technical systems of manufacture and use within which the artifacts are embedded.[13] Such a perspective emphasizes that the practice of technology is deeply embedded within the social order and involves much more than the development and use of various machines and tools. Because technology is such an intimate part of the strategy which individuals and groups employ in their dealings with the world, it is impossible to identify a sharp boundary separating technology and society. What is important, is to become sensitive to patterns of relationships linking technology and society at any given time, and to be ready to look for the ways in which technical changes alter the existing distribution of benefits and burdens for individuals, social groups, and the natural environment. The ten claims which follow plus the associated "System of Technology" concept map emphasize both the intimate connections technology has always had with human experience and the impact of technology upon the natural world.

The View From History

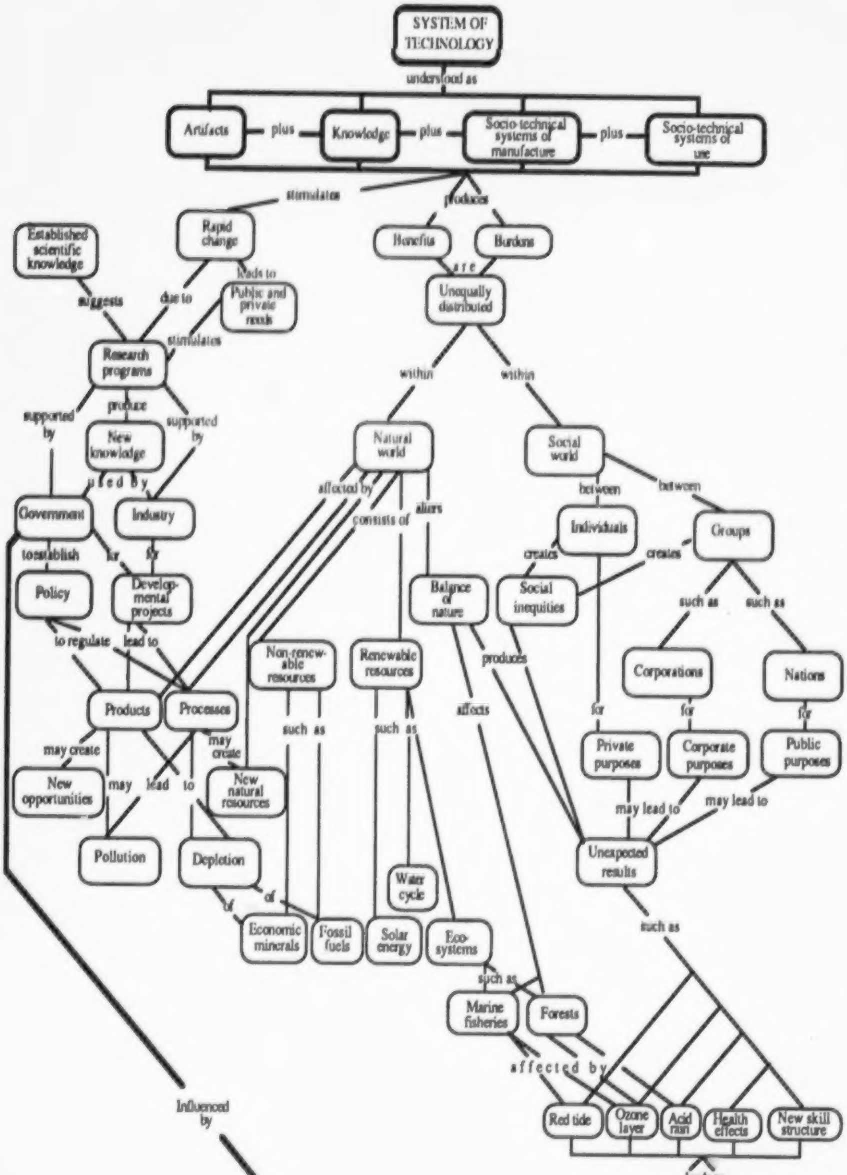
T1. Human beings are technology users--that is how we have always made our way as a species.

T2. The social and environmental problems of the modern world (e.g. erosion due to deforestation, salinization due to improper irrigation techniques, shifts of military power due to the development of new weapons) are similar to those which have always faced human societies. The uniqueness of the contemporary situation lies in the power, rapidity of development, and the wide scale of application of modern science-based industrial technology.

T3. Significant decisions about technology always involve questions of social equity and environmental quality because they allocate resources and the opportunities of individuals and/or groups to use those resources.

T4. Changes in the technical system (e.g. the transportation and manufacturing changes which were part of the industrial revolution, etc.) usually confer both benefit and burdens upon individuals and communities. Often the benefits go mainly to one group while the burdens are born by others.

T5. Technological changes are always implemented and supported by particular individuals, groups or organizations to achieve their particular goals.


SYSTEM OF TECHNOLOGY
understood as
Artifacts
plus
Knowledge
plus
Socio-technical systems of manufacture
plus
Socio-technical systems of use
stimulates
produces
Rapid change
Established scientific knowledge
Benefits
Burdens
leads to
are
Public and private needs
Unequally distributed
suggests
due to
stimulates
Research programs
within
within
supported by
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New knowledge
Natural world
Social world
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Private purposes
Corporate purposes
Public purposes
New opportunities
may
lead
to
New natural resources
may lead to
may lead to
Pollution
Depletion
Water cycle
Unexpected results
of
of
Economic minerals
Fossil fuels
Solar energy
Eco-systems
such as
such as
Marine fisheries
Forests
affected by
Influenced by
Red tide
Ozone layer
Acid rain
Health effects
New skill structure
leads to
Public attitude shifts
Private actions

T6. Significant technological changes always have unintended and unforeseen environmental and social consequences.

The Current Scene

T7. Decision making about complex technological issues usually involves trade-offs (compromise) among alternative courses of action. Often the trade-offs involve weighing the benefits and burdens for people and the environment.[14]

T8. The specialized training and experience of technical experts encourages the development of a characteristic tunnel vision which makes it difficult for them to recognize the importance of the STS web and to take account of the STS connections.[15]

T9. We share a persistent tendency to assume that the development of more powerful technologies will inevitably lead to social progress.

T10. Technological decisions are always made within a context of uncertainty.

Values in Science and Technology

The underdetermined character of scientific knowledge (S3), the impossibility of designing an experiment which will unambiguously prove or disprove an hypothesis (S2), the influence of theoretical assumptions upon observations (S1), and the role of sociological processes in establishing criteria of adequacy (S7) all provide an opening and a requirement for personal and social values (S10) to supplement the standard set of values used by the scientific community in the appraisal of theories. The hyper-fractionalization of the scientific community into innumerable invisible colleges (S5, S6) helps to explain why personal and social values are so difficult to identify except through historical case studies or the disputes which characterize expert disagreement in public controversies. The century and a half which separates us from Charles Darwin's England enables us to recognize the ways in which his assumptions reflected the influence of a social and cultural setting much different than our own. Similarly, the characteristic interdisciplinary nature of expert disagreement often brings into the same arena of discussion scientists from widely separated invisible colleges who have come to internalize very different ways of seeing the world--ways which bring with them characteristically different patterns of social assumptions (S8, S10). In brief, we need to understand that there is an inherently subjective element in all scientific claims which cannot be eliminated either by more precise measurements or by devoting more careful attention to critical self-examination. On the other hand, it is equally important to understand the self-corrective features of modern science which serve to reduce (in the course of time) excesses due to ideological commitments of individuals or the corporate invisible colleges within which scientists work. Scientific claims are always open to challenge by individuals or groups who are moved by different ideological values. As more or better empirical information becomes available, scientific claims remain vulnerable to criticism and reinterpretation.

If our major task in understanding science is to become more sophisticated in recognizing the subjective element, in technology we need to focus our attention on learning the art of understanding artifacts as political documents. Technologies do not come into existence or use by themselves. They are always the product of individuals or groups seeking to serve their particular interests in ways shaped by their particular understanding of the world (T5). This is true whether their purposes are essentially selfish or public spirited. Furthermore, technological innovation always involves questions of social equity (T3). For these reasons it is imperative that we become much more skilled at recognizing the political dimensions of technological artifacts than we are at present. If we try to find technological solutions to social and political problems without recognizing that the artifacts of technology already bear the imprint of social and political values, our 'solutions' will often pose more problems than they solve.

While the characteristic products of science and technology are very different, the individuals who create them and the organizations within which they are created are often the same. The scientist/technologist--whether he or she works in an industrial, a governmental, or an academic setting--often comes to adopt its characteristic ideological values. If the members of the 'invisible college' within which the scientist/technologist works are largely employed by organizations of the same type, then ideological biases springing from both science and technology may strongly reinforce one another and it may be difficult indeed to recognize and deal with their consequences. We need to become much more competent in identifying and assessing the consequences of value commitments embedded in contemporary science-based technology.

Concluding Comment

The exercise of writing this paper, especially the construction of its concept maps, has helped me to recognize more clearly that an adequate approach to understanding STS issues must be based both upon a recognition of the ways in which society penetrates science and technology (e.g. the roles played by of sociological factors and value-laden decisions in science and technology) as well as the more familiar territory of unexpected consequences and social equity issues. The twenty claims about the systems of science and technology plus the associated concept maps are an attempt to bring together these two aspects of the STS equation. The claims laid out in this paper are not intended to be read as self-evident truths which any sensible person should accept. Indeed, each one merits extensive discussion. They are an initial effort to summarize, organize and condense into a relatively brief list some of the more important ideas to be found in the literature of science and technology studies in order to make that literature more easily accessible researchers and teachers concerned with the K-12 environment. I hope that they will serve both as an encouragement to K-12 teachers in their efforts to integrate STS issues into the courses they teach, and as a reminder to STS scholars of the importance of seeking to establish as broad agreement as possible about the core concepts which should become part of the public understanding of science, technology and society.

Acknowledgement

The author would like to acknowledge the critical readings given to the paper by Peter Asquith and David Wright of Michigan State University and by Ned Woodhouse from Rensselaer Polytechnic Institute.

Notes

[1] There is an excellent discussion of concept maps in chapter 2 of **Learning How To Learn** by Joseph D. Novak and D. Bob Gowin (New York: Cambridge University Press, 1984).

[2] The classic discussion of the theory-dependence of observation is **Patterns of Discovery** by N.R. Hanson (Cambridge: Cambridge University Press, 1958). A good introductory discussion may be found in the third chapter of **What Is This Thing Called Science** by A. F. Chalmers (New York: University of Queensland Press, 1982).

[3] The design of an experiment is dependent upon many assumptions. These include the hypothesis being tested plus the theoretical assumptions on which the hypothesis is dependent and the assumptions employed in the construction and operation of all apparatus used in the experiment.

[4] This is the problem of induction. For a highly readable introduction to this aspect of

scientific argument see the first two chapters of **What Is This Thing Called Science** (cited above in note 2).

[5] There are approximately 100,000 primary papers published each year in the larger scientific disciplines such as physics or chemistry.

[6] Members of an invisible college communicate by letter and by telephone, visit each others laboratories, arrange and attend conferences of mutual interest, and give post-doctoral appointments to each other's students. These informal connections are mirrored in their research papers as they cite one another's work.

[7] The critical process through which criteria of adequacy are established within an invisible colleges combines both formal elements (e.g. published papers, the actions of editors and reviewers) and informal elements (e.g. conversations at conferences, the subtle coaching of graduate students in the technique of experimental design). The criteria of adequacy adopted by various invisible colleges often differ greatly--particularly if the invisible colleges represent widely separate components in the spectrum of scientific studies. An excellent case study illustrating this point is "The Role of Cognitive and Occupational differentiation in Scientific Controversies," (**Social Studies of Science**, 6: 349-368 (1976). John Ziman makes the important point [**An Introduction to Science Studies**, (New York: Cambridge University Press, 1984)] that within the system of science there are very few ways of resolving disputes between members of different invisible colleges. In many cases criteria of adequacy are tacit rather then explicit and can only be acquired by participating in the ongoing research life of a particular invisible college.

[8] Robert K. Merton suggested as early as 1942 that many of the characteristic patterns of behavior of the scientific community could be explained if its members acted in accord with a small number of basic norms.

[9] Within science the appraisal of competing theories is a difficult and a crucial task. It is difficult because as claim S3 noted, the generalizations of science always extend beyond the empirical observations which give them support. Furthermore, there are no rule guided procedures available to scientists for the appraisal of competing theories. Consequently, scientists must rely upon what McMullin calls "oblique modes of assessment." [See Ernan McMullin, "Presidential Address," **PSA 1982: Proceedings of the 1982 biannual meeting of the Philosophy of Science Asociation,** ed. Peter Asquith and Thomas Nickles (East Lansing, Michigan: The Philosophy of Science Association, 1982) Vol. 2, pp. 1-23.] In their judging of theories, scientists use a series of criteria such as predictive accuracy, internal coherence, external consistency, unifying power and fruitfulness. These criteria function as values in the appraisal of theories. Because their use in theory choice is widely believed to improve the "conformity between theory and world,"(see McMullin, pg. 17) it is appropriate to call them epistemic values. While there is broad agreement across the scientific community concerning what the major epistemic values are and that they should serve as tests for the "goodness" of a theory, there is no agreement concerning what weight should be assigned to each criterion when comparing theories.

[10] In recent years a substantial literature in the history and sociology of science has provided many examples of respected scientists who have been significantly influenced by a wide range of personal and societal values. Many examples can be found in the literature dealing with controversies related to topics such as environmental quality, health, weapons systems, and race. Such socially mediated values may lead to subtle shifts in scientific judgment or to a quite conscious bias in favor of theories, explanations , and interpretations which further a particular social or ideological position.

[11] Probably most philosophers of science would agree with McMullin that in the normal

course of science, biased judgements due to the influence of social values (he calls them "ideological values") will be gradually eliminated through the continued application of the standard values used to appraise theories. That is, science is continually being cleansed from any contamination due to social values as "...scientists attempt to duplicate experimental claims; theoreticians try to extend the theories involved in new and untried ways; various tests are devised for the more vulnerable moves involved, and so on." In general sociologists of science are much more skeptical about the possibilities of gradually eliminating theoretical judgements biased by the influence of social values. A good introduction to the sociology of science is **Science in Context: Readings in the Sociology of Science**, edited by Barry Barnes and David Edge (Cambridge, Massachusetts: MIT Press, 1982).

[12] See Alvin M. Weinberg, "Science and trans-science," **Minerva** 10: 209-222 (1972); and "The limits of science and trans-science," **Interdisciplinary Science Reviews** 2: 337-342 (1977).

[13] Stephen Klein, **SSTS Reporter**, Vol. 2, No. 4.

[14] Claim T7 is a close paraphrase of "understanding" IV.C.5. of the the New York Middle School Science Syllabus, **Block J: Science, Technology and Society**, (New York State Department of Education, 1986).

[15] See **The Culture of Technology by Arnold Pacey** (Cambridge, Mass: MIT Press, 1983) for an interesting discussion of the "tunnel vision" of experts.

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HIGH-RISK TECHNOLOGY AND TECHNOLOGICAL LITERACY

Joseph R. Herkert

The explosion of the space shuttle Challenger in January 1986 followed by the Chernobyl nuclear accident in April of the same year caused a great deal of attention to be focused upon the perils of contemporary technology. Rarely, if ever, have two highly-publicized accidents involving humankind's most sophisticated technologies occurred within such a brief span of time. The purpose of this paper is to make some remarks about the similarities between these two events, the relationship of complex, high-risk technologies such as these to the theme of technological literacy, and the role the STS community can play in the resolution of issues concerning high-risk technologies.

Similarities Between the Challenger and Chernobyl Accidents

The Challenger and Chernobyl accidents had a number of notable similarities. Both, for example, involved complex, "high-risk" technologies which are susceptible to mishaps of the type that Perrow (1984) calls "normal accidents" or "system accidents". Perrow argues convincingly that it is characteristic of "complexly interactive" and "tightly coupled" systems such as these to *inevitably* experience "multiple and unexpected interactions of failures" which are incomprehensible to system operators. A major implication of this is that the continued application of technological fixes to complex systems such as nuclear power plants and space shuttles is not likely to eliminate system accidents. Indeed, it may lead to *more* accidents as a result of increased system complexity (Perrow, 1984; Bowonder and Linstone, 1987).

A second similarity between the Challenger and Chernobyl accidents is that both can be regarded as "technological catastrophes". Chernobyl resulted in 31 deaths and over 200 injuries from the explosion, fire and acute radiation exposure of plant personnel and emergency workers. Estimates of the long-term effects of Chernobyl have ranged from 0 to 75,000 new cancers (Marshall, 1987), making it potentially one of the most catastrophic industrial accidents to date.

The Challenger explosion, on the other hand, resulted in the loss of "only" seven astronauts. In what sense then, can Challenger be construed as a "technological catastrophe"? As Perrow (1986) has pointed out, the presence of a plutonium payload on a subsequent shuttle flight represents a *potential* catastrophe. I would also argue that the Challenger explosion was a *symbolic* disaster. Perhaps no other event since the assasination of President Kennedy held the nation in such a sustained state of mourning. While Americans honored the memory of the astronauts, many also shook their heads in disbelief over the loss of the Challenger, which to them symbolized, along with the other orbiters, the invincibility of American technology. While it may be argued that this faith in technology was misplaced, the image of the Challenger exploding will no doubt be etched in the minds of Americans for years to come.

A third similarity between the Challenger and Chernobyl accidents is that both technologies are characterized by an arrogance or smugness on the part of the experts involved, whether they be managers, engineers or scientists, who tend to operate under the premise that their technological know-how is capable of "fixing" any problem which may arise and of operating the technology safely or at least at a "safe enough" level.

In the case of Challenger, the technology was promoted as safe enough to fly ordinary citizens--Congressmen, payload specialists, and a school teacher--while at the same time NASA was ignoring a long history of internal concerns over the adequacy of the booster rocket seals and numerous other items which threatened flight safety. As Professor of Management William H. Starbuck told *IEEE Spectrum*: "...there is something magical about this group of people at NASA that can somehow surmount these risks. I think they developed a feeling of invulnerability" (Bell and Esch, 1987).

Such technological arrogance is not, however, confined to capitalists. Prior to Chernobyl, Soviet scientists and engineers made such remarkable claims as "nuclear power plants do not affect the health of the population" and "properly supervised power plants [are] 100 percent safe" (Hawkes et al., 1986). Perhaps this explains why Chernobyl's operators turned off plant safety systems during a test procedure they conducted while the reactor was still in service!

The credibility of the promoters of a technology can be seriously, if not irreparably, damaged when the public is continually assured that the technology is foolproof, only to have an embarrassing array of multiple failures come to light during the investigation following an accident. Indeed, in the case of both the Challenger and Chernobyl accidents, the postmortem has revealed a history of serious design problems, poor management, and operator error (Marples, 1986; McConnell, 1987). Although these are not *causes* of the accidents as much as they are attributes of the complex systems involved (Perrow, 1984), the revelation of such failures no doubt engenders public mistrust of experts.

A final similarity between Challenger and Chernobyl is that both present stunning examples of the use of "risk assessment" in misleading the public with respect to the likelihood and severity of accidents with high-risk technologies.

Nobel physicist and Rogers Commission member Richard Feynman argued in his critique of the Commission's report on the Challenger accident, that based on past performance the reliability of solid rocket boosters is at best a 1 in 100 chance of failure (which translates to 1 in 50 flights since the shuttle has two boosters). For a Department of Energy (DOE) study of the risk of a shuttle exploding while transporting a radioactive payload, however, NASA had supplied a figure of 1 in 100,000 chance of booster failure that it had based upon "engineering judgement". NASA, which at that time did not even conduct formal risk assessments, nevertheless pulled a number out of the air to assist DOE in reassuring the public that the danger of launching plutonium into space aboard the shuttle was negligible (Marshall, 1986).

The American government and nuclear industry, like their Soviet counterparts, have long been in the habit of "reassuring" the public in a similar manner. The reaction of the U.S. nuclear industry to the Chernobyl accident, for example, was that there is little to be learned by the U.S. from the accident. As the Atomic Industrial Forum (AIF) (1986) indicated in a public affairs release: "*...because of large, fundamental technological differences, the Chernobyl accident appears to have little significance for the safety of U.S.-type reactors*" (emphasis in original).

Despite the differences in U.S. and Soviet reactor designs and safety requirements, however, at least one lesson should be clear. Like Three Mile Island, Chernobyl demonstrated that system accidents resulting in reactor core damage can and will happen (Ahearne, 1987; Davies, 1986).

Indeed, at the 1987 annual meeting of the American Association for the Advancement of Science (AAAS) members of the scientific community began to offer candid appraisals of the likelihood of nuclear accidents. Robert Gale (1987), the American bone marrow specialist who assisted the Soviets in treating the victims of Chernobyl, suggested that there is at least a twenty five percent probability of another major nuclear accident in the next ten years, while a resource economist argued that 3.5 core melts could be expected over the operating history of the 128 U.S. reactors then currently operating or planned (i.e. roughly one every ten years) (Chapman, 1987).

Such back of the envelope estimates, which have been based upon recent experience and common sense, ring truer than the formal, multi-million dollar risk assessments sponsored by the U.S. nuclear industry. One risk assessment study for a nuclear plant, for example, concluded that the median expected frequency of an accident resulting in one or more early deaths was 1 in 110 million reactor years, while the median frequency of an accident causing one or more long-term cancer deaths was 1 in 15,000 years (Gueron, 1984).

Both the Chernobyl and Challenger examples would appear to lend credence to the assertions of Perrow (1984), Winner (1986) and others that the purpose of much "risk assessment" is merely to justify high-risk technologies to a wary public.

Challenger and Chernobyl, then, as well as other examples of actual or potential mishaps with high-risk technologies--such as the Bhopal chemical leak, breakdown in the U.S. air traffic control system, and accidental nuclear war--demonstrate that the technologies involved are far more complex and prone to failure, and potentially more catastrophic, than the experts have been willing to admit to the public and even, perhaps, to themselves.

It is worthwhile to pause here for a moment to consider that what is at risk in the way we handle complex technologies extends beyond the public health and safety, as well as beyond any symbolic loss, although each of these risks is quite important in their own right. What is often overlooked in discussions such as this, however, is that the costs of system accidents often extend far beyond the parameters of conventional risk assessments, including substantial economic costs to both the owners of the technology and the economy at large, as well as adverse public reaction to the technology in question and other complex technologies (Slovic, 1987).

The Challenger accident, for example, has resulted in at least a two and one half year grounding of the U.S. shuttle program and costly delays for a number of space missions. There have been no new orders for nuclear plants in the U.S. since the accident at Three Mile Island. The Chernobyl accident has not only heightened public concern over nuclear power in the U.S. (Ahearne, 1987), but has also resulted in unprecedented public opposition to nuclear plants in the Soviet Union (Keller, 1988). It would appear that the promoters of high-risk technology can not afford very many more Challengers and Chernobyls.

The High-Risk Technology/Technological Literacy Connection

It is a widely held view that the points I have been raising with respect to complex technology are the domain of experts, and that, given the current level of technological literacy in our society, the public lacks the ability to effectively participate in discussion of these issues. For example, in his compelling account of the Challenger accident, McConnell (1987) notes:

> Perhaps it is impossible to form proper policy about complex high technology within a democratic political system such as ours. Clearly most voters do not understand modern technology....How would such people be able to form correct attitudes about high technology in general and our space policy in particular?"

As Waks (1987) has noted, however, the STS conception of technological literacy extends beyond the mere understanding of technology to the "possession of basic concepts and skills to participate in the technology-dominated economy and understand technology-dominated social issues and participate meaningfully in their resolution." Achieving technological literacy thus requires not only the possession of basic technical concepts and skills but also concepts and skills regarding the cultural, social, political and economic dimensions of technological systems. In this broader view of technological literacy, experts who lack an understanding of the connections between technology and these other dimensions might also be considered "technologically illiterate" (Roy, 1987).

Indeed, research on perception of risk and on risk communication has led to the conclusion that public perception of risk, though different from that of experts, is nonetheless legitimate, and, therefore, the resolution of issues concerning risk requires two-way communication based upon mutual learning and respect. (Slovic, 1987; Plough and Krimsky, 1987) As Slovic (1987) has noted: "Each side, expert and public, has something valid to contribute. Each side must respect the insights and intelligence of the other."

In this context, rather than viewing technological literacy as an *obstacle* to dialogue between experts and the public on issues concerning high-risk technology, discourse on high-risk technology which focuses both on the technical and societal aspects of the problems at hand should be looked upon as a *means of increasing* the technological literacy of both the experts and the public.

One way the STS community can help to facilitate such communication is to encourage experts in government, industry and academia to stop "reassuring" the public with misleading information concerning complex technologies and to begin to level with the public with respect to the true nature of these technologies. In particular, the promoters of high-risk technology need to acknowledge that:

1. The design, construction, *and operation* of such technologies is, indeed, a risky business.

> 2. Many accidents can be prevented at a cost. [Opinion polls have consistently indicated that the public is willing to pay a price for increased environmental health and safety (Schneider, 1986).]
>
> 3. Even under the best of circumstances, catastrophic accidents will continue to happen. Reaping the benefits of complex technologies will inevitably entail bearing the costs of catastrophes every few years.

Such an admission, I would argue, is an essential first step in seeking a resolution to the dilemmas posed by complex technologies. This step is needed both to restore the damaged credibility of experts which has resulted in the aftermath of technological catastrophes and to purge arrogant attitudes about the perfectibility of technology. From there the discussion can turn to mutual consideration of the means of reducing the magnitude of catastrophic accidents and the complexity of technological systems, including, perhaps, the abandonment of some technologies (Bowonder and Linstone, 1987).

The STS community can also contribute here by helping to inform the public with respect to the technological and societal issues involved in the resolution of problems arising from complex technologies and by seeking to provide them with the means of making informed decisions concerning the deployment of such technologies.

For example, those of us involved in education can structure new courses or course units around specific high-risk technologies. I have recently been involved with two of my colleagues at Lafayette College in the development of a new colloquium for senior Bachelor of Arts students entitled "Technological Catastrophes" which utilizes the Challenger, Chernobyl and Bhopal accidents as case studies. The goals of the course include introducing the students to basic technical concepts, as well as providing them with critical insights regarding the techniques utilized in the evaluation of risks and benefits, the reasons why technological catastrophes occur and how they can be prevented, and the many value choices, implicit and explicit, that figure into the selection of technological systems.

One "risk" of the approach which I have advocated in this paper--replacing the posture of "public reassurance" with frank discourse between experts and the public on the nature of complex technologies--is that the technology in question will be abandoned. Perhaps a more likely outcome is that the technology may be restricted in certain ways: e.g. humans would be sent into space only when essential, or nuclear reactors adjacent to urban areas would be closed down.

These prospects may not be very agreeable to the promoters of high-risk technologies. To continue misleading the public, however, also runs the risk of abandonment of these technologies in the event of catastrophic system accidents. One thing is certain: the public will not accept continually being deceived with respect to the likelihood and severity of technological catastrophes, only to hear in the wake of such accidents a litany of things that have gone wrong.

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EDUCATING FOR CITIZENSHIP: WHAT STUDENTS NEED TO KNOW ABOUT TECHNOLOGY

James L. Steele

Introduction

Positivism, or naturalistic science, is very much alive in American society. The notion that science is an objective activity and one that is value-free permeates the naturalistic ideology. This ideology dominates media interpretations of science and is held, for the most part unquestioningly, by a large percentage of beginning college students. The naturalistic notion of objective, value-free science has an important transfer to technology, since students usually define technology as "applied science." This is one of the most pernicious myths we face in attempting to lead students to an understanding of the holistic nature of technology. Viewing technology simply as applied science results, too, in giving technology an almost deterministic and uncontrolled nature with no relation to creativity, choice and values. It ignores the fact that technology is a cultural activity that takes place within a socio-historical context for specific economic and political ends.

Technology-Practice

Pacey (1983) does an excellent job of debunking the "technology is neutral or value-free" perspective. He argues that the multi-dimensional aspects of technology can better be understood by talking about what he terms "technology-practice." The three essential components of technology-practice are organizational, technical and cultural.

The organizational aspect reflects the political realities of administration and public policy. It organizes and structures the activities of designers, engineers, technicians, and production workers. It is also concerned with the consumers or what Pacey terms the "users" of produced artifacts. The technical aspect of technology-practice deals with technical knowledge, skill, and design. This is the realm of the technical expert who constructs machines and makes things work. The cultural aspect of technology-practice encompasses the ideological components of technical and scientific activity: the beliefs about change and progress, the commitment to discovery, invention, and creativity; and the internalization of personal and professional values which lead to the pursuit of technical goals. Together, the components of "technology-practice" expand our understanding of technology to include human and social aspects, as well as the purely technical.

Technology and Values

The relationship between values and technology has a history with roots embedded in classical political economy. It is a relationship addressed by Marx and Weber, critical theorists of the Frankfurt School, social theorists following Ellul, existentialists following Heidegger, and many others. It is a history students should confront because, as Volti observes: "Technological change is often a subversive process that results in the modification or destruction of established social roles, relationships, and values" (1988: 16-17).

The nature of the relationship between values and technology is not without ambiguity (Winner, 1986b). In the Machine in the Garden (1964), Leo Marx demonstrates the conflict and dialectical relationship between values, technology and change as he traces the intrusion of values associated with progressivism/industrialism into the pastoral writings of early American thinkers such as Jefferson, Hawthorne, Melville, and Thoreau.

Taking a different approach, Mesthene (1972; 1986) views technology as the progenitor of both opportunities and problems for society. His perspective is reflected in the view of Lynn White, who observed, "A new device merely opens a door; it does not compel one to enter" (Mesthene, 1972: 117).

While the nature of the relationship between values and technology is a philosophical and empirical problem of no small dimension, it is a pilgrimage students should take. To explore the relationship between technology and values in its many dimensions can be an enlightening and rewarding experience for any student. Students should be given the opportunity to explore relationships between ideas, machines and values which, in a social, political and economic context, establish important parameters of the technological society in which they are living and will be working.

Technology and Choice

We cannot, indeed, we need not introduce students to every technology, for any technology may serve as a paradigm for enlightenment. The selected paradigm should lead to the demystification of the technology and set it in a socio-historical context with economic, political, and cultural consequences. Students should learn the process of thinking about and evaluating technology and the social implications with which the technology is intertwined. Such learning becomes transferable to any technology, even those not yet on the horizon, but with which students must deal as adult citizens.

Citizens who live in a modern, industrialized society have a fundamental need for scientific and technological literacy in order to function effectively. Waks (1986) is correct, however, to point out that not all citizens will play the same active or informed role in the political process. A technologically literate "critical mass" is needed, nonetheless, to ensure that political choices will reflect a cross-section of informed democratic participation. But, developing a technologically literate citizenry is a challenge for any society. Technological literacy is complex and a universally acceptable definition is difficult to achieve. A reasoned attempt is the definition that appears each year in the program of the National Technological Literacy Conference: "Technological literacy means understanding the technological and scientific forces shaping our lives and being able to act on this understanding for our personal welfare and the common good."

Students must be helped to understand that choices are real and important. They must learn the difference between decisions and choices. A technological imperative does not mean technological determinism. Weizenbaum stated it well:

> Technological inevitability can thus be seen to be a mere element of a much larger syndrome. Science promised many power. But, as so often happens when people are seduced by promises of power, the price exacted in advance and all along the path, and the price actually paid, is servitude and impotence. Power is nothing if it is not the power to choose. Instrumental reason can make decisions, but there is all the difference between deciding and choosing (1976:259).

There are alternative courses a society can take, but changes have costs as well as benefits. Winner observed that "Choices about supposedly neutral technologies ... are actually choices about the kind of society in which we shall live" (1986:315).

Responsibility of the Academy

In a society where change is ubiquitous and technological change compelling, it is incumbent upon the academy to prepare students for the life-long responsibility of choosing between alternative courses of action and making informed policy decisions. Unfortunately, most students are not being introduced to the changing, emerging forces until they leave the university. This means that the college, at best, has shortchanged them or, at worst, failed them. Students are enthralled by genetic engineering, with the use of gene splicing and other techniques of genetic alteration to "create" new life forms, extend life or cure disease, but they are confused about the value issues of growing and saving fetuses for spare parts.

Students are fascinated with robotics but understand little about the ways their working lives will be affected by microelectronics. They know nothing about computer-aided design or the attempt to unite it with computer-aided manufacturing to develop the totally automated factory. They have difficulty conceptualizing the structure of communication systems which produces a fully automated office. And, they are not sensitive to the consequences of these changes for displaced workers, for de-skilled workers, for dissatisfied workers, or for despairing workers.

No other area promises such rewards or portends greater problems for individuals in societies than the area of technology and society. The dangers can be minimized if we enlighten our students, if we help them develop needed conceptual skills and understanding, if we make it possible for them to develop beforehand the model of society to which our emerging technologies can take us, and if we lead them as citizens to actually choose and pursue the humane model.

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KNOWLEDGE AND SKILL BASE ENTERING AND WORKING IN THE WORLD OF TECHNOLOGY

Donald Maley

This presentation deals with a number of different dimensions of a very complex problem facing educators, and our managers of industries and businesses in this latter par of the 21st century. The complexity of the issue is magnified by the fact that the "world o technology" is not just one big homogeneous entity. It is fraught with differences in detail magnitude, simplicity, complexity, technical proliferation, composition, impact, an human requirement, as well as realized and unrealized potential and change.

One approach to this issue is to look at the qualities or characteristics of that world o technology. It is a world experiencing an accelerating change with much of the chang related to changes in technology. Figure 1 is a graphic presentation of the acceleration o change resulting from the impact of technology. Thus, preparation for working in a changing world is essential.

A second characteristic is that it is knowledge based.

> ... we have systematized the production of knowledge and amplified our brain power. To use an industrial metaphor, we now mass produce knowledge and this knowledge is the driving force of our economy. (Nasbit, 1982, p. 16)

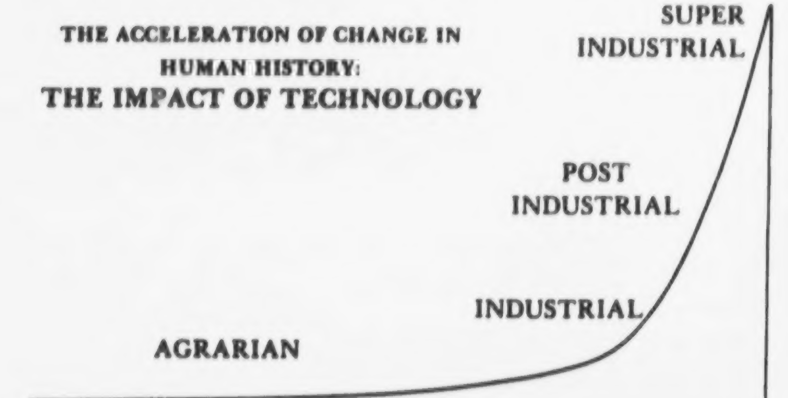

Figure 1

Knowledge has increased, in just about every field, and our technologies, in most cases, have become more sophisticated, requiring a great deal more knowledge if there is to be understanding of such items or systems.

A third characteristic of the modern technological world is the skill requirement with respect to the use, control and maximum utilization of the technology. The human functions that control, manipulate, guide and maintain the effective use of today's technologies have multiplied and diversified. These human functions are in many instances skills that incorporate the manual and mental into what may be termed a human function management system.

A fourth characteristic of the technological world is the pervasiveness of technology. That is, the influence and impact of technology is omnipresent, regardless of time or place, in most industrialized societies, and certainly here in the United States.

The Role of the School Systems and Colleges for Providing Background and Skills for Entry into the Workplace in a Technological World

The topic is one that generates strong feelings on both sides of the issue. On the one hand, there are the "educational purists" who claim that their role is strictly one of developing the educated person with little regard for preparation for the world of work.

The other extreme is that of the "trade school" approach in the public secondary as well as higher education. It is one that sees the employment of graduates to serve the special needs of business and industry for trained and educated personnel as the exclusive missions of education.

Each of these positions is characterized by the "blinder" perspective that is inappropriate in a highly industrialized and advanced technological society. The more appropriate position is somewhere between these two extremes, but with the recognition that it would not be the same program for all.

One of the issues that must concern educators in preparing personnel for entrance into the technological workplace is relevance -- relevance with respect to the educational product being in line with the needs of the employing agencies. This takes the form of assuring that graduates are equipped to deal with the realities of the workplace and that the educational preparation must be directed towards that reality.

Keer and Pipes (1987) discuss the need for a more pragmatic approach to engineering education. The criticism of engineering education appears to center on its own emphasis on engineering science and much lesser emphasis on engineering design. They state: "... all engineering schools need to systematically change their programs to restore the balance between engineering science and design ..." (p. 41)

> "U.S. engineering graduates lack of exposure to design and manufacturing partly explains the country's disadvantage in developing well-designed and well-manufactured products. We find it telling that General Motors relied on German engineering to design the 1988 Pontiac Le Mans ..." (p.40)
>
> "The vast majority of newly graduated engineers are trained for analysis positions and are rarely exposed to design engineering practices," says Frank M. Sanders, chairman of the design engineering technical committee for the American Institute of Aeronautics and Astronautics. (p. 40)

Change and the Human Requirements in a Technological World

The one word that appears to characterize much of what education should be concerned about as well as reflect in its processes is change. This phenomena of change imposes some needed personal qualities on the citizen and the worker in industry or business. Adaptability, coping capability and flexibility appear frequently in the literature as human requirements in a changing society.

Alvin Toffler (1974) comments on the needs of the individual in a changing world.

> ... The ultimate purpose of futurism in education is not to create elegantly complex, well-ordered, accurate images of the future, but to help learners cope with real life, crises, opportunities and perils. It is to strengthen the individual's practical ability to anticipate and adapt to change ... (p. 73)

Moss (1987) concluded that:

> Perhaps more attention should be given to improving worker flexibility and the adaptability by (a) attending to the conditions of learning (how one learns and how well one has learned) that will maximize transfer to the content taught and (b) developing values and attitudes that recognize the need for change in occupational skills and promote a willingness to learn new skills in order to remain productive. (p. 66)

The Task Force on Education for Economic Growth (1983) presented the following commentary on the impact of technology in the workplace.

> In one sense, the advance of technology in the workplace makes work easier by reducing physical demands. But inevitably the advance of technology makes other intellectual and psychological demands. Even those inventions that make calculations faster and easier -- computers, for example -- require a high degree of adaptability. (p. 14)

The ability of the individual to deal with the changing nature and requirements of the contemporary workplace is in many respects related to the person's attitude and psychological outlook. Seeing change in a positive light and the potential for involvement or participation in what is happening are important.

Flexibility and Broad Range of Skills

There has been considerable discussion over the past few years regarding the breadth or narrowness of skills for the worker in the technological workplace. Here again the matter of size of organization and the nature of the work performed play important roles in this decision.

The trend towards a more flexible and broader range of skills requirement was a point made by Katz and Sable (1985).

> ... The trend is away from producing a standard car with specialized resources -- using workers with narrowly defined jobs and dedicated machines. Instead, automakers are learning to produce specialized cars with general-purpose resources -- broadly skilled workers and machinery that can be reprogrammed or adapted to make various models.
>
> ... Most automakers now agree that flexible deployment of labor will be crucial. Workers need an expanding range of skills. (p. 57)

The expanding range of skills provides for greater job security for the individual by increasing his/her mobility on the labor market. It also has advantages for the employer in that personnel may be moved or coordinated with worker needs in the production system. There also is a certain advantage in the in-plant or organized retraining efforts of the company. One obstacle to the broad flexible skill proposition has been the labor unions and their agreements with management. This resistance has in some areas changed with a union attitude more flexible than in the past.

Skills Needed in the Technological World of Work

There are two broad categories of skills that are essential for the individual employed in the technological workplace. The first are the skills that are indigenous to a given operation, job or kind of position. The second category of skills are those that are more generalized and common across the broad technological world. These are the skills that have been identified by many writers and authorities regarding human requirements for effectiveness in the workplace of a technological society. Such skills include communication, learning to learn, problem solving, coping, calculating, observing, analyzing, reading and writing.

The skill of learning to learn has become an important human requirement in the technological workplace. Some years ago during a question and answer session as a part of a White House meeting on "Human Resource Development in the World of Work," Ed Sutton of the New Your Telephone Company (AT&T) presented what AT&T was looking for in new employees. (Training and Development, 1977)

> What we're looking for when people come to work at AT&T is the ability to do the job we bring them in to do ... which really means their ability to move into the training and learn! (p. 19)

Alvin Toffler (1970) in support of the need for learning to learn commented: "Tomorrow's illiterate will not be the man who can't read: he will be the man who has not learned to learn." (p. 367) This may in fact be one of the most important skills of an individual in a technological work world.

The skill of learning is essentially the individual's central power system that energizes the person and which will enable him or her to generate the potential in each. This need to learn is accentuated by the uncompromising demands of a society that is undergoing an unprecedented acceleration of change. This change phenomena has placed increasing demands on the individual as industries update equipment, processes, and procedures as well as products and services.

The skills in communication are also vital in the technological workplace. This includes all forms of verbal and written communications.

John Naisbit (1982) discusses the importance of communication in an information age in the following comment:

> ... as Daniel Bell has said. During our agricultural period, the game was man against nature. An industrial society puts man against fabricated nature. In an information society -- for the first time in civilization -- the game is people interacting with other people. This increases personal transactions geometrically, that is, all forms of interactive communications: telephone calls, checks written, memos, messages, letters and more ... (p. 18,19)

John Connors, former Director of Human Resources for Martin Marietta Corporation and consultant to industry provided the following response to the question of skills needed in an advanced technological society.

> ... don't overlook the importance of articulation. A real familiarity with meanings of words, with the principles of effective writing and effective speaking, with the importance of combining speaking skills with "presence" is likewise important.

Solomon and Gutcher (1987) concluded that "communications skills were apparently considered more important in terms of educational requirements in an electronics technology curriculum than many technical tasks." (p. 90)

"English or communications" ranked the highest of all tasks identified in the study which involved 118 technicians and 122 supervisors in electronics technology industries.

The problem solving skill represents another area of importance to the worker in the technological world. That ability to identify, define an analyze problem situations is an increasing requirement of the contemporary worker.

Alfred S. Warren (1977) of General Motors Corporation noted that industry needs and wants problem-solving skills. "G.M. wants the same things society wants from the education systems ... people who can read, write and do math well, who have some coping skills and problem solving skills, and an understanding of our economic system." (p. 11)

The recognition that the worker is, and can be, a problemsolver accomplishes two very important functions. It provides the worker with an identity of higher proportion as opposed to another cog in a train of gears. Secondly, it provides management with personnel who have a piece of the action and a greater degree of ownership.

Understanding in Mathematics, Science and Other Disciplines Applicable to the Workplace

A workplace dominated by technology places new demands on many employees for increased understandings in the areas of mathematics, science, economics, social studies, environmental studies, health and safety. If one is to work in an environment that is technologically controlled and impacted, it will require that individual to have a level of technological literacy regarding the processes and systems in that workplace.

Technological literacy (NSF 1983) "is the possession of a reasonable understanding of the behavior of technological systems and requires knowledge of scientific and mathematical concepts." (p. 74) This technological literacy must go far beyond the processes of technical operations and processes in manufacture of a given product or service. Concern for the health and safety of the working personnel and how such concerns are dealt with give further evidence of need for understanding growing out of the sciences, social and environmental studies as well as economics.

Another important area of interdisciplinary understandings that becomes increasingly important is in the environmental impact of the plant and its operations. The frightening revelations of polluted waters, polluted air, acid rain, nuclear waste disposal, chemical dumping, lack of security with nuclear materials, chemical seepage and food preparation laxities all call for increased understanding in getting to the remedies as well as making an assessment of their impact.

The Human Dimensions of Work in a Technological World

Much attention has been given to the need for greater knowledge and understanding in the areas of mathematics, sciences, economics, sociology and environmental studies. Likewise considerable stress has been given to the need for improved skills in calculating, problem solving, reading, communicating, analyzing and synthesizing. There is still another important series of competencies that must be given serious attention or the possession of the previously listed understandings and skills will go for naught. That third series of competencies may be called the "human aspect of work."

Robert Nelson (1977) listed a series of "survival skills," including:

1. Working in an organization
2. Understanding self and others
3. Motivation for work
4. Interpersonal relations
5. On-the-job communication
6. Using creativity on the job
7. Authority and responsibility
8. Problem solving
9. Coping with organizational conflict
10. Coping with organizational change
11. Leadership
12. Adapting and planning for the future

(pp. 65, 66)

Many of these skills are not dealt with in the formal school setting. They are in too many cases left for the individual to learn "the hard way" by the process of what one might term "on the job enculturation."

Summary of Skills and Understandings Needed

The role of the school (secondary, post-secondary and higher education) may be seen more clearly if one were to examine the particular qualities, skills and understandings that business and industry are looking for in their workers. A number of such requirements have been identified in the previous discussion and will be listed in a form of summary under three different headings -- operational skills, understanding and knowledge, and human qualities.

Operational Skills

1. Communicating (written, spoken)
2. Learning
3. Reading (written matter, graphs, charts, maps, instruments, tables, schematics)
4. Inquiring
5. Analyzing
6. Problem solving
7. Following directions
8. Leading
9. Thinking
10. Planning
11. Measuring
12. Decision making
13. Technical skills (specialized and broadly based)
14. Evaluating

Understanding and Knowledge

1. Mathematics
2. Science (physical and biological)
3. Safety
4. Economics and the economic system
5. Health

6. Human behaviors
7. Labor relations
9. Industrial sociology
10. Drafting/design
11. Computer science

Human Qualities

1. Adaptability
2. Flexibility
3. Interpersonal relationships
4. Creativity and ingenuity
5. Ambition, self achievement
6. Self understanding
7. Assuming authority and responsibility (Nelson)
8. Coping with technological changes
9. Coping with organizational change (Nelson)
10. Coping with organizational conflict (Nelson)
11. Working win an organization (Nelson)
12. Integrity

The human qualities requirements listed above are unique (in concern) to the contemporary industrial/technological workplace. These are concerns that have had very little attention in the industrial period, largely because of the role the individual played in the factory or manufacturing establishments. This, in part, is again due to changes in technology, products, working conditions, role of the individual, and of course the rate of change.

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MODELS OF SCIENCE AND TECHNOLOGY IN TEACHING CHILDREN TO READ

Constance Weaver

Without even being aware of the STS movement, I have for years been concerned with "technological literacy," the idea that our citizenry must be able to think and make informed decisions about technological issues and the effects of science and technology upon our world. One of these effects is the effect upon education, typified by the ways in which we teach children to read.

What I hope to demonstrate is that a concern for technological literacy cannot be separated from a concern for emerging literacy among young children, for predominant in our schools is a mechanistic, reductionistic, "technological" concept of reading and of how children learn to read, a concept that mitigates against their developing any kind of literacy at all. The fact that the majority of young people do become at least functionally literate is a tribute not to the reading instruction to which they are subjected, but to the complexity of the human mind and our innate drive to make sense of our world.

This concern about a "technological" approach to reading is shared by many in the field of English education and reading, and in particular by the other members of the Commission on Reading of the National Council of Teachers of English. With Kenneth Goodman as the senior author, we have prepared a Report Card on Basal Readers that documents these concerns (Goodman et al. 1988; for a short summary, see Watson and Weaver 1988). Unfortunately, reading instruction is dominated by a basal reading series in approximately 90% of American schools today (Anderson et al. 1985). A basal reading series is not merely a set of books for children to read from; it is a comprehensive program consisting of pupil books with reading selections, teacher's manuals that tell the teacher exactly how to teach the lesson, workbooks and dittos, tests and more tests, plus various other paraphernalia. The fact that a 55-page pupil book for first grade can be accompanied by a teacher's manual of 350 pages, as well as all the other materials, should itself cause us to ask, "What's going on here?"

The Report Card on Basal Readers documents in detail how basal reading materials and instruction came over half a century ago to be based upon concepts from classical science, behavioral psychology, business and industry, and how these outmoded concepts are still reflected in most basal reading series today. Such concepts lead to the aforementioned "technological" view of teaching and learning, which is characterized by such assumptions as the following (Weaver 1988, pp. 181-183):

1. The learner is passive.
2. Children will learn only what they are directly taught.
3. Knowledge is constructed "bottom up" from elemental building blocks, from the smallest parts to increasingly larger wholes.
4. Errors reflect a learner's failure to learn and/or apply what has been taught.
5. What's important is the measurable product of instruction, not the process of learning.

To quote from the Report Card on Basal Readers, "In this view learning is the result of teaching, piece by piece, item by item. The whole, reading, is the sum of the parts, words and skills. Learners are passive and controlled" (p. 99). In such a view, teachers are not expected to be responsible professionals who make informed decisions; they're "scripted technicians," most of whom do in fact follow the directions, the scripts, in the teacher's manuals (Anderson, et al. 1985). And of course, children are reduced even more, to manipualted parts in the educational machine.

This view might not be detrimental to learning to read if it actually reflected how people read, or even how children learn to read. But it reflects neither.

Let us consider, first, some examples that should help to demonstrate that proficient readers do not read primarily by going from part to whole: that they do not build meaning by decoding words letter-by-letter, or by determining the meanings of sentences word-by-word, or even by determining the meanings of paragraphs and larger wholes sentence by sentence. Try, first, to read the following paragraph of a version of "Little Red Riding Hood," told from the wolf's point of view (Weaver 1988, p. 63):

-nc- -p-n - t-m- th-r- w-s - h-nds-m- y--ng w-lf n-m-d
L-b-. L-b- l-v-d w-th h-s m-th-r -nd f-th-r -t th- -dg- -f - d--p,
d-rk w--ds. -v-r- d--, L-b- w-nt t- h-nt -t th- -dg- -f th- w--ds,
n--r th- l-ttl- v-ll-g- -f C-l--s.

Surely it is clear from even this brief example that when we can use semantic and syntactic cues, we do not decode words letter-by-letter as we read. It should be equally clear that we do not need nearly all the graphic clues normally available to us.

What, then, of building the meaning of sentences word-by-word? A brief example should again suggest the impossibility of such a procedure. Take, for instance, the word "run." How would you define it? See if your definition or definitions are appropriate for the following sentences (Weaver 1988, p. 16):

1. Can you run the store for an hour?
2. Can you run the word processor?
3. Can you run the 500-yard dash?
4. Can you run in the next election?
5. Can you run next year's marathon?

6. I helped Samuel with his milk run.
7. They'll print 5,000 copies in the first run.
8. Sherry has a run in her hose.
9. There was a run on snow shovels yesterday morning.
10. It was a long run.

In how many of these sentences did your definition, or definitions, fit? Clearly we cannot take meanings for words out of our mental dictionaries and simply fit them into the sentences we're reading; we have to determine what each word means in combination with the other words. We do not build meaning merely sentence-by-sentence, either, but by using everything we know to construct relationships among words and sentences. That is, in order to construct meaning as we read, we must have and use adequate background knowledge, and we must continually apply various strategies to make sense of the sentences and words on a page. Meaning is not merely the end of reading, the product, but the beginning and the means as well.

If learning to read were significantly different from mature, proficient reading, there might still be justification for part-to-whole technology in teaching children to read. However, children who learn to read in the home, or in what are nowadays often called "whole language" classrooms, learn to read in much the same way as they learned to talk (e.g. Holdaway 1979; Harste, Woodward, and Burke 1984; Teale and Sulzby 1986; and for an excellent summary, Newman 1985). Starting with an intention to make meaning, they tend first to read a book holistically, telling the story from the pictures or reciting the memorized story. Then, gradually, they fill in the parts: they learn to recognize the words (at first, only in familiar contexts) and begin to grasp some of the correspondences between letters and sounds. Thus for young children too, meaning is the beginning and the means of reading, not merely the end.

Let us consider, as an analogy, how children learn to speak their native language. Imagine, if you will, the following scenario (Weaver 1988, p. 176):

> A young mother greets her husband enthusiastically as they sit down to dinner. "Guess what, dear? I've found this marvelous program for teaching Johnny to talk. It's called 'Getting Back to Basics: Teaching Your Child to Talk.' It's a great program. It starts first with the basic sounds, like /d/ and /æ/ -- you know, like in dog and apple. First you teach the child to say these sounds in isolation and then you teach him to blend them together. Why, in a couple of weeks Johnny might be able to day 'dada'."

Fortunately, in this scenario, the woman's husband is not impressed. He dismisses his wife's suggestion by commenting that he never heard of a child being "taught" to talk that way, one sound at a time, blending sounds to make words.

We do not directly teach children to talk. We do not teach them rules for putting sounds together to form words and words together to form sentences -- partly because we do not consciously know most of the rules ourselves. For example: unless you have had some training in linguistics, you probably do not know the "rule" for making regular verbs past tense. Like becomes liked, with a /t/ sound to indicate past tense; love becomes loved, with a /d/ sound; and hate becomes hated, with a vowel plus a /d/. But why? What is the "rule" that governs these regular patterns? Clearly even if we did know these rules, it would be futile to try to teach the rules directly to infants. Fortunately, however, children do not need to be taught the rules directly.

In short, the way children learn to talk is characterized not by a mechanistic, reductionistic, technological model of learning, but by a transactional model that reflects not classical science, but the paradigm offered by quantum physics, the "new" paradigm emerging in a variety of disciplines. This paradigm can be contrasted point-by-point with the paradigm that underlies much of today's education, and certainly much of the instruction in today's basal readers. According to this paradigm (Weaver 1988, pp. 181-183):

1. The learner is active, gradually formulating increasingly sophisticated hypotheses about the environment in order to learn.
2. Children do not learn merely, or even mainly, what they are directly taught.
3. Knowledge is not simply constructed "bottom up," from smaller parts to increasingly larger wholes. Rather, the whole is achieved by working at least as much "top down," by drawing upon one's entire lifetime of knowledge, experience, and cognitive strategies.
4. Errors often reflect the learner's current stage of development; as such, they are not necessarily to be viewed as "wrong."
5. What's most important is the process of learning. Paradoxically, focusing on the process of learning rather than the measurable product of instruction generally produces more sophisticated and more long-lasting products.

This paradigm describes, as I have indicated, the way in which children learn to talk and, later, the way in which they learn to read most naturally. But when these same children begin school, we often treat them as if the only way they could or would learn is through the "technology" of the basal reader, a totally opposite approach. According to the NCTE Reading Commission's Report Card on Basal Readers, underlying virtually all of the basal reading series available in the United States today is the assumption "that the learning of reading can happen skill by skill and word by word and that learning is the direct result of teaching" (Report Card, p. 125). Not only are "decoding" and word recognition taught skill-by-skill, but so is comprehension.

The difference between the kinds of materials typically used in our schools and the kinds that facilitate learning to read more naturally can be illustrated by an excerpt from a major American basal reading series and an excerpt from a little book in the Ready to Read set of materials that are used in New Zealand. Both would be approximately first grade level, or perhaps kindergarten:

Excerpt from Economy Level C, Pre-Primer

The Dog in the Van

Did I see a dog?
I did!
The dog went into the van.
Did I see a red dog?
Is the dog red?

Is a dog in the van?
Is it red?
Is a red dog in the van?

I did not paint the dog.
I did not paint Happy.
Happy went into the paint.

The dog is red.
The paint made it red.
I did not see a red dog.
It went into the van.
A red dog is in the van.

Excerpt from the Ready to Read series

Greedy Cat, by Joy Cowley

Mum went shopping
and got some sausages.
Along came greedy cat.
He looked in the shopping bag.
Gobble, gobble, gobble
and that was the end of that.

(Subsequent episodes have identical language, except for the new item that Mum buys. Finally, she buys a pot of pepper -- and that is the end of that!!)

In the first selection, we can see concern for repeating words time and again, to ensure mastery; we also see an attempt to use primarily words that reflect regular letter/sound patterns (the short vowel sounds, for example). However, the "story" as a whole is virtual nonsense, and the reader cannot very readily use context or cognitive schemas to predict what will come next. This is in sharp contrast to what readers do normally, as we began to understand from reading the "Red Riding Hood" passage. We use our knowledge of syntax, the developing meaning of a coherent text, and our lifetime of experience to predict as we read. The selection about the dog in the van thwarts such productive reading strategies.

The book Greedy Cat, on the other hand, encourages such prediction, because the episodes repeat with only a word or phrase being changed. Furthermore, reading is enhanced by the rhythm, and by the rhyme in the third and sixth lines. Such features in beginning reading materials help make books like Greedy Cat as easy to read as possible, whereas the materials found in the early levels of most basal reading series make reading and learning to read as difficult as possible.

In sum, then, both reading and learning to read are in many respects whole-to-part processes that begin with what the learner brings to the task, both in the way of cognitive processing strategies and specific knowledge and experience. The fact that most basal reading materials adopt a part-to-whole approach, and most teachers teach reading that way, does not mean that it is typically learned that way. In fact, there is considerable evidence that the poorer readers tend to be the ones who try to read using little more than the skills they have been explicitly taught, while the better readers intuitively use more sophisticated and more productive strategies. Janet Emig's summary of the teaching-learning relationship seems particularly applicable to the direct teaching of reading: "That teachers teach and children learn no one will deny. But to believe that children learn because teachers teach and only what teachers explicitly teach is to engage in magical thinking" (Emig 1983, p. 135).

To put it bluntly, the mechanistic, reductionistic, technological paradigm is simply not an appropriate model for literacy education. The fact that millions, even billions, of children have learned to read with basal readers is a tribute not to the technology of basals, but to young children's drive to make sense of the world, including the world of books and print. But why should we persist in reading instruction that thwarts rather than facilitates children's natural strategies for making sense of the world? Paradoxically, freeing ourselves from a "technological" concept of reading instruction is vital in order to better facilitate "technological literacy."

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LANGUAGE AND CULTURE: THE CONTEXT OF STS EDUCATION

Gayle L. Ormiston and Raphael Sassower

Linking Theory and Practice

Concerns over technical education are neither new nor limited to STS programs in the United States. The eleventh edition of the Britannica (1911) contains an interesting discussion of technical education by Sir Philip Magnus, who notes a difference between modern technological teaching and the mechanical practices of manufacturing and commerce. Teaching science and technology in schools is different from the apprenticeship method employed for the acquisition of specific "technical" skills. But what constitutes the difference? According to Magnus, students "should be so taught as to become instrumental in the formation of mental habits and the development character, the mere knowledge or skill acquired being of secondary importance."(1)

Magnus' remarks apply in a limited fashion to the general field of Science, Technology, and Society (STS). We cannot ignore the difficulty of determining what is to be included in the study of STS, and devote our attention exclusively to the means by which we present the material to others -- especially students. Besides, do we need to mention anything about "science" and "technology" as subject matter, if our concern, according to Magnus, is indeed the development of mental habits and character in our students, or what amounts to the development of technical skills for properly conducting our thoughts and actions?

An American contemporary of Magnus, Charles Sanders Peirce was also interested in the pedagogical difficulties and methodological issues associated with the clear presentation of ideas. Dissatisfied with what he took to be Descartes' conviction for a priori truths (a conviction fundamentally pleasing to reason), and suspicious that Leibniz's recommendations would not lead beyond the clarification of linguistic use, Peirce put forward another method for determining the clarity of ideas: the "pragmatic maxim." "Consider what effects, which might conceivably have practical bearings, we conceive the subject of our conception to have. Then, our conception of these effects is the whole of our conception of the object."(2)

Peirce's advice is more useful for our purposes than is Magnus'. Peirce's concern challenges the very conceptions we may have of our material, convictions which might be pleasing to reason or mere theoretical considerations, speculations that have no bearing on practice. Instead of thinking about science and technology in exclusively "theoretical" terms, we must incorporate our theoretical concerns with other issues of practice. The clarity of perception, and, therefore, the clarity of presentation, depends on recognizing that ideas make sense only when they are placed into action, that is to say, comprehended according to the conditions of a specific context. This linkage between the theoretical and practical constitutes the framework in which our pedagogical discussion must take place.

From the Interdisciplinary to the Meta-Disciplinary Character of STS Education

Our effort to compose a text in STS traces one feature of Peirce's maxim. Theory -- conceptualization -- is born in practice, refined through inquiry, the practice of putting ideas into play as hypotheses, so to speak, and returns to practice in our attempts to realize the differences our conceptions make in the interrelation with other ideas. If the study of science and technology is to contribute to the development of "mental habits," to use Magnus' term, or if it is to bring about a certain kind of critical awareness or enlightenment regarding the ubiquity of technology, then it must make a difference in action. It must generate some change. According to Peirce, "the conceivably practical" is the "root of every real distinction of thought, no matter how subtle it may be; and there is no distinction of meaning so fine as to consist in anything but a possible difference of practice."(3) What difference does STS make to education in general, and to university/college education in particular? What do we suppose is its pedagogical force and significance? What are our convictions -- a priori -- in this regard?

The difference any form of education makes is the difference it makes in our actions. The child who receives a burn from the flame on a gas range does not "experience" the flame in an isolated fashion. The experience is embedded within a certain context, a network which includes optical, muscular, and neural responses and associations. From such an experience, the child will understand how to avoid being hurt again in the same or similar circumstances, especially when pain is viewed as a series of related actions. Here reason informs the child based upon a certain experience. However, the critical engagement of reason, where reason turns, in a Kantian and Hegelian fashion, to examine its conditions, capacities, and functions, or what we might call the critical use of theory, results in an enlightened speculator. But, if there is no action forthcoming, one remains merely an enlightened speculator. To be sure, reason's critical function is a significant ingredient in the invention of concepts.

STS promises to make a difference. It promises to create a context within which "education," broadly construed, can be revaluated, can be redesigned, reconceived to meet the technological and scientific demands it (STS) claims to examine, not to mention the attendant political, cultural, theological, and aesthetic questions associated with the so-called "advancement" of science and technology.

What is so unique about STS? In one respect, it is inherently interdisciplinary, as its title suggests. But is STS to be appreciated simply as another inter-disciplinary program? We suggest this is not the case. Of course, there are several ways to conceive inter-disciplinary studies. One would be to emphasize the ostensible overlap of different disciplines, where the methods of inquiry typical of specific disciplines are joined to study a specific object or problem. We can imagine this situation with political philosophy, political science, and sociology; aesthetic theory, the history of art, and literary criticism; or molecular biology, physiology, and organic chemistry.

A second way might be to focus on "science and technology" as the "objects" of inquiry from a fusion of several disciplinary perspectives. In this way, one might focus on only the political aspects of science and technology; the challenge to theological beliefs due to the increasing changes in our lives effected by advances in science and technology; or the ethical consequences pertaining to the use of certain scientific and technological innovations.

A third way might be to take science and technology as the foundation for examining the contemporary status of a specific discipline. For example, one can imagine examining certain styles of contemporary art on the basis of the technologies employed to generate certain aesthetic effects and illusions. In a similar fashion, the advance of political science or physical geography could be examined in terms of their dependence on the actual and potential use of computer technology.

STS challenges not only the traditional disciplines but the interdisciplinary approaches as well. As such, we recommend that STS be understood as meta-disciplinary. The importance of the meta distinction rests on our realization that STS obliterates all traditional disciplinary boundaries. It forces its practitioners to work, to think, to write in many different genres at once. Its work takes place between these boundaries, where no one method, conceptual apparatus, or scholastic conviction succeeds on its own. Thus, there is no "object" per se, no "philosophy of technology," set apart from the inter-relation of thought, language, practice, and culture. If STS is to make a difference, it must be seen as going beyond the boundaries, the intellectual segregation of disciplinary inquiry.

A Cultural Critique: Reconstructing a Linguistic Framework

One way of reexamining classical images of science and technology, and the metaphors used to identify the boundaries that mark the universe of discourse for each, is to ask anew, "What are the linguistic (i.e., cultural) conditions under which our conceptions of science and technology and their implementation develop?"(4) Identifying these conditions will assist our understanding of the exaggerated fears and dreams which have traditionally guided our responses to scientific and technological innovations. In order to achieve this focus, we examine an interpretive framework that takes into account, and gives an account of, the historical conditions, literary (i.e., fictional) responses, philosophical debates, and the linguistic conditions which inform the theoretical and practical dimensions of science and technology.(5) In establishing such a framework, we can achieve a preliminary recognition that in contemporary discourse a common foundation can no longer be presupposed.

The unique feature of this critique is that it directs attention to the determining role language plays in establishing the conditions of reciprocity -- between science and technology, between science and the humanities, and between technology and the humanities. For the purposes of this project, "language" is no longer conceived of simply as a tool or a set of tools by which we describe a particular state of affairs, "worldly" conditions, or the theoretical and practical reciprocity of science and technology. Nor is language conceived of merely as a tool for prescribing the conditions of human activity. Rather, based on the writings of Wittgenstein, J.L. Austin, Derrida, and Foucault, "language" is understood in a more productive or performative sense: language creates the conditions which make its performance possible, it creates the culture in which it is performed. The cultural critique undertaken in this project is, then, a linguistic critique which presupposes and, as such, develops an interpretation of language's "power" in constituting its cultural conditions.(6)

Notes

An earlier version of this paper was presented at the Third National Conference on Technological Literacy, February 7, 1988, in Washington, DC. The discussion here stems from our book, The Convergence of Science and Technology: A Cultural Critique, Englewood-Cliffs: Prentice Hall, Inc., forthcoming).

1. Encyclopedia Britannica, 11th edition. New York: Macmillan, 1911, Vol. 26, p. 497.
2. Charles Sanders Peirce, Collected Papers, edited by Paul Weiss and Charles Hartshorne. Cambridge, MA: Harvard University Press, 1931-35, 5.402.
3. Ibid., 5.400.
4. Cf. Michel Foucault, The Order of Things (New York: Vintage Books, 1973).
5. Jean-François Lyotard, The Postmodern Condition, translated by Brain Massumi and Geoff Bennington. Minneapolis: University of Minnesota Press, 1984.

6. Cf. the most recent discussion of these conditions and their effects is described by Ivan Illich and Barry Sanders in A B C: The Alphabetization of the Popular Mind. San Francisco: North Point Press, 1988.

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MODELS AND STRATEGIES FOR A SCHOOL-INDUSTRY-COMMUNITY APPROACH TO REFORMING THE K-8 SCIENCE CURRICULUM WITH AN STS EMPHASIS

Frederick A. Staley

Introduction

Many national reports suggest new efforts to be made to better prepare today's youth for a more scientific and technological future society. In response to these calls for reform a three year project funded by the National Science Foundation and Arizona State University is assisting school districts in the west Phoenix, Arizona, area establish, implement, and sustain a scientific-and-technological-literacy-for-all-students approach within their school curricula.

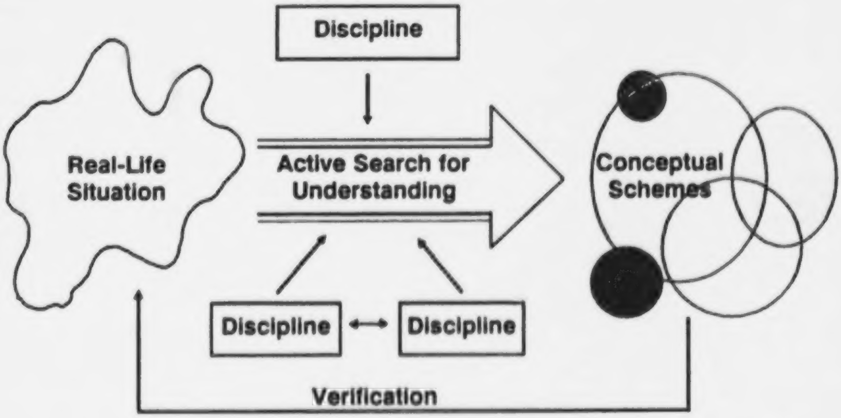
Two broad goals of this project are to:

1. Begin to modify and eventually reform the existing science curricula of participating school-communities so that they have more of a science, technology and society (STS) emphasis.
2. Accomplish the above with an emphasis on the school-community as the unit of change. A school-community is defined as a school's principal, teachers, children, parents, and district wide businesses,industries and informal education agencies involved in technological and scientific endeavors.

Curricular Reform

A curriculum with an STS emphasis is being designed which highlights the development of problem finding, problem solving and decision making skills as students study topics, issues and problems appropriate for their level of development and relevant to the scientific, technological and social past, present and future of Phoenix, Arizona, America, planet Earth and the Universe. Such a curricular emphasis permits students to understand and appreciate the relationship between scientific concepts, the technology leading to or resulting from science and the implications of both science and technology for present and future society. The following models and organizational structures serve as the basis for the curricular reform efforts in this project:

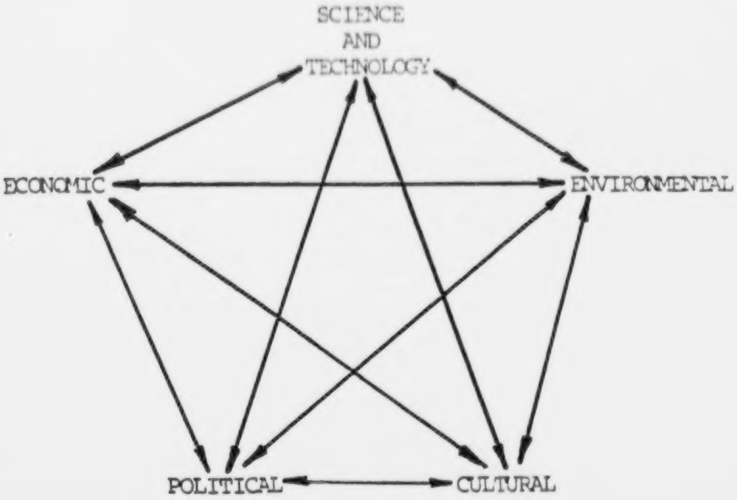
1. Hickman's (1984) "Real-Life Situations" Curricular Model:


Discipline
Real-Life Situation
Active Search for Understanding
Conceptual Schemes
Discipline
Discipline
Verification

Source: Faith M. Hickman, "A Case Study of Innovation" in Redesigning Science and Technology Education, 1985.

In this model real-life STS topics, issues or problems which are relevant and meaningful to the students serve as themes for instructional units created by teachers, rather than the physical-chemical, life-health or earth-space discipline-bound topics which typically serve as organizers for science curricula. As an STS topic is investigated many

WORLD SYSTEMS VIEW

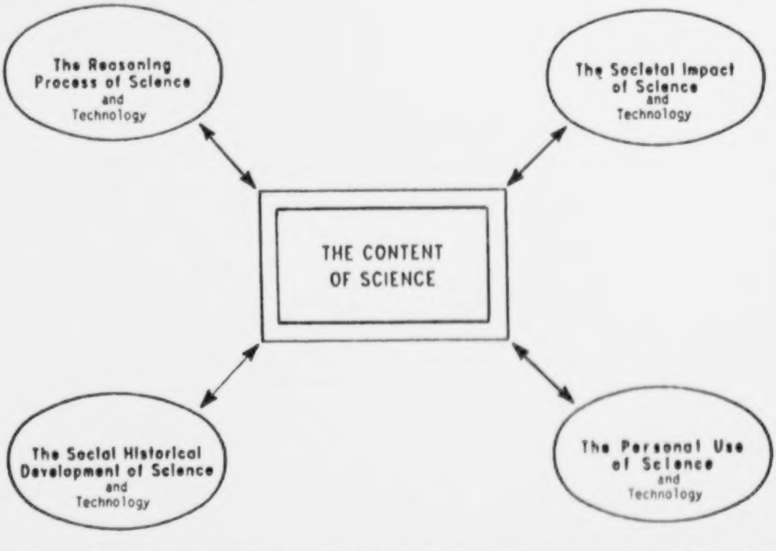

SCIENCE AND TECHNOLOGY
ECONOMIC
ENVIRONMENTAL
POLITICAL
CULTURAL

disciplines are drawn upon to help understand the theme and to express this understanding in some form. While these investigations are going on, problem finding, problem solving and decision making skills are stressed. The search for understanding leads to the acquisition of conceptual schemes which help students understand the big picture of scientific, technological and social interaction in the topic under study. The student then uses these conceptual schemes as tools in the study of other STS topics.

2. McGowan's (1987) "World Systems View" of Global Issues:

In this model the search for understanding of any topic, issue or problem is viewed from perspectives of interdependent and dependent scientific and technological, environmental, economic, cultural and political world systems. The model suggests one cannot understand, let alone begin to work toward the solution of any science or technology issue or problem without examination of the environmental, political, economic and social dimensions. Thus, STS topics must be taught in an interdisciplinary manner.

3. A modification of Far West Laboratory's (1987) "Scientific Literacy Model" as a Definition and Organizer for STS Units of Study:


The Reasoning Process of Science and Technology
The Societal Impact of Science and Technology
THE CONTENT OF SCIENCE
The Social Historical Development of Science and Technology
The Personal Use of Science and Technology

Based on research in middle school classrooms, the Far West Laboratory suggests that any reform of the science curriculum ought to help students understand all the above ingredients of scientific literacy. The heart of science and technology, according to the Far West Laboratory, is its content. This means those large conceptual schemes which Hickman refers to in her model. This content can be approached and understood from any of four different vantage points, or windows. You'll note that in addition to a window dealing with reasoning skills, the model also deals with ingredients often associated with STS; namely social/historical development, societal impact, and personal use of science and technology. The Far West Laboratory's model of Scientific Literacy, including the words and concept of technology, provides a workable definition of STS for teachers desiring to create their own STS units.

School-Community Unit of Change

As we move into the twenty-first century it is clear that those in the formal schooling system need help and guidance from those outside the formal school network to more adequately prepare our youth for the future. A model of education calling on the resources of the entire school-community is needed to replace the present, limited mode of schooling.

In this project the school principal is the key figure in bringing together teachers, key parents, key students and community business, industry and informal education representatives. These individuals discuss the possibilities of what life will be like for their students in the twenty-first century, decide what it is their school community ought to be doing to better prepare these students for this future and develop an action plan to do these things.

Each school-community action plan identifies, among other things, the role business, industry and informal education institutions in the school-community might assume. While individual action plans vary, the following types of roles are being assumed by many companies:

1. Providing personnel from all levels of employment to visit schools and classrooms to act as resources when appropriate STS topics, issues, problems and resources are being studied.
2. Providing resources such as publications, equipment, visuals, computer software and hardware, and products that teachers and students can use when studying appropriate topics.
3. Providing tours of facilities for children or teachers.
4. Helping to develop and judge such school events as Science Fairs, STS Fairs, Appropriate Technology Fairs, Science Olympics, and Invention Conventions.

Preparation of Participants for Reform

To prepare school-community members for curricular reform and cooperative activity the following types of in-service opportunities are being provided.

1. A day and a half of workshops for principals dealing with the rationale for and nature of STS reform and the important role of the principal in the process.
2. A series of 10 afterschool or Saturday workshops for the STS Resource Teachers selected by each school-

community. These workshops are put on by representatives of 15 science and technology companies or institutions in the west Phoenix valley, i.e., utility company, local newspaper, museums, civil air patrol, World Future Society, etc.

3. A three week summer STS Content Academy for the STS Resources Teachers. This is a series of seven intense lecture/presentations by Arizona State University faculty from Engineering and Social Sciences. Field trips to 10 different science and technology-oriented research centers dealing with the topics under discussion in the Academy are also included.

4. A two week summer Methods Academy for the STS Resource Teachers. This follows the other two academies and provides teachers an opportunity to begin to convert their new knowledge and experience with resources and STS content into thematic units. Additional instructional activities and strategies for working with other members in the school-community once the STS Resource Teachers return to their schools are also developed.

5. A series of academic year workshops and independent study activities which include workshops on Project Wild (1986), Project Learning Tree (1987), our computer bulletin board/data bank system, thematic unit development and expanding relationships with business/industry and informal educators.

6. A half day workshop for business/industry and informal education representatives on the rationale for the project and their importance to the project.

Products and Outcomes of the Project

In addition to better preparing students for a more technological, information oriented, future society, the outcomes and products of this project are beneficial to other schools within the original project districts, other school districts wishing to reform their curriculums with a STS emphasis, and to the welfare of all science and technology oriented businesses, industries and informal education institutions in the west Phoenix area.

The following represent products and outcomes which are currently anticipated:

1. A Science, Technology and Society Data Bank/Bulletin Board containing the thematic units created by Resource Teachers, reviews of locally and nationally developed STS curricular materials, reviews and suggested uses of public television programming dealing with STS topics, descriptions of local resources (agencies, organizations, people, companies) and updated lists of possible STS topics, issues and problems.

2. Information and research about effective strategies and approaches for creating interdisciplinary instructional STS thematic units for elementary/middle school students utilizing local resources and dealing with societal issues that have community relevance.

3. Descriptive and longitudinal research data about the process and effects of attempting to bring about substantial change in the science curriculum utilizing a

school-industry-community approach.

4. Benefits of business and industry such as: a) improved education of students who will provide a reservoir of future scientists, engineers and technicians to serve as employees, b) higher quality of elementary and middle schools and school systems which will attract additional quality employees to the area, c) a better educated general population who are able to make more informed political and societal decisions based on science and technology foundations, d) an improved corporate image, and e) more opportunities for employees to provide a community service.

Conclusion

It is not the intent of this project to implement any one program or philosophy of STS curricular integration. Rather, this project is attempting to develop and share a process for bringing about substantial curriculum reform utilizing the principal, designated STS Resource Teachers, locally developed activities and thematic units and district wide technology and science oriented businesses, industries and informal education agents as key ingredients in the reform process.

Undertaking of this project requires a definite shift in focus in the way of bringing about change and in the nature of the change that is required in the preparation of today's youth for the future. As Hurd(1983-84) pointed out:

> The outcry for higher levels of scientific and technological literacy is a plea for fundamental reform in science education. The tenor of the discussions is to bring science education into harmony with modern conditions of science ,technology, and society as they are interrelated in the welfare of the individual and the nation. The basic issue is not the current insufficiencies of science education but the more fundamental question of the place of science and technology in the wider texture of life.

In addition to better preparing students for a more technology, information oriented future society, the outcomes, research and products of this project are available to other schools and school districts wishing to reform their curricula with an STS emphasis.

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CRITICAL THINKING DEVELOPMENT IN MIDDLE SCHOOLS USING STS ACTIVITIES

Darrel W. Fyffe

Introduction

Many arguments support the need for our schools to seriously attend to the teaching of thinking. Proficient thinking is not a necessary culmination of experience or schooling. Teaching critical thinking skills is justified as a part of the educational experience. Perkins says:

> "Everyday thinking ... is a natural performance we all pick up. But good thinking ... is a technical performance, full of artifice. ... People tend not to consider the other side ... look beyond the first decent solution ... or ponder the problem before rushing to candidate solutions ...." (Perkins, 1985)

Students in our schools will perform a complex activity, to function in a technological world whose form and direction no one has yet experienced. They will benefit from engagement in a varied, life-long curriculum. One needed change is an increased emphasis upon the development of critical thinking skills that is substantially more complex than the past efforts to teach "process science." A second change is that of introducing children to scientific, technological and societal issues through the teaching of science. Students in our schools must be educated in the sciences and have an understanding of the technological issues with which they will be confronted.

Past Actions

The past leadership for the education of teachers and curriculum recommendations has been assumed by the "science" disciplines. The federally funded science curriculum projects of the 1960's resulted in programs skewed toward the aim that greater numbers of science specialists (engineers, scientists, technicians, etc.) would result.

During the 1960's and early 1970's, the literature of science education referred to the development of "processes" in students, a vision of student learning aimed in the right direction but which missed the critical point for several reasons. The processes were seen as a means of getting students to think as scientists.

Recent professional actions, as revealed in conferences and the literature, has been a rapid growth in the development of science curricula based upon themes from scientific, technological and societal issues - a movement identified as STS science. This movement is grounded in a desire for a broader understanding of the role of science education and scientific literacy than has existed.

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The past 30 years has seen the development and spin-off of technological discoveries. With a subsequent decline in the interest in and value placed upon science, during and following the war in Vietnam, the field of science education is rebounding to the vigor in thought and action that ought to have marked it during the past.

STS Critical Thinking

Instruction in problem solving has long been an interest of the field of science education. Much has been written of the need for students to develop the skills of problem seeking, selection of an approach and attempts at solution. Effective teaching of critical thinking skills would require changes in the materials, approaches and teacher/student interactions. Making such modifications is often best accomplished with some directed experience and coaching. The opportunity to assist the schools with such issues is a clear need for in-service education of a somewhat different mode.

Decision making, as just one aspect of the critical thinking skills, consists of several skills or actions. The most common elements are:

- enlarging the conceptual understanding,
- problem identification,
- understanding sequence or order,
- alternative solution generation,
- determination of the consequences,
- consideration of the consequences in terms of the values, and
- selection and design of an alternative or cluster of alternatives.

We must avoid the view that all scientific decisions are managed in this manner or that students will consciously use all these stages in every personal decision. However, students should be skilled in applying the process to complex decisions with which they are confronted.

Classes may be introduced to the decision making process by giving them real-world problems and information. One means of doing that is to use issues that we characterize as science - technology - society (STS). Many issues may be drawn into the current fields of study to introduce students to the broad issues facing our society. These may be drawn from prepared STS resources or from items in the news today. Current events often lead to important issues of STS relevance.

We need to understand the function of problem solving and decision making in the education of children, especially in the intermediate and middle school grades. Epstein (1980) identified changes in the developmental characterization of students from age 11 to age 15:

Table 1

Percentage of Students in Various Developmental Stages

Developmental Stage	Age 11	Age 15
Pre-Operational	6	1
Concrete Onset	49	14
Concrete Mature	40	53
Formal Onset	5	19
Formal Mature	0	13

The data illustrates the rapid change in the learners during the four years of the middle-grades. During this time much of the thinking strategy and background skills are acquired.

Involvement of the Student

Increasingly, we find that technological developments invade or even dominate our daily lives. Our food, clothing, transportation, and communication are affected. Our fears for survival and the ability to inhabit this sphere have been intertwined with the technology of the recent past. Increasingly, we will be engaged in the scientific and technological culture to deal with ideas, issues and opportunities which have never before existed.

Some will be involved with the technological process or products mainly as consumers, but requiring an understanding of the natural and built environment. Changes which occur before children born this year reach adulthood, in 2006, will be immense.

Many will find that the need to change types and locations of employment and the prospects for advancement will require the mastery of knowledge, skills and attitudes relating to the sciences, technology and societal interactions on a level never required before in human history. This will require that all students (citizens of the world) become enabled to:

> "... experience a sense of potency about their ability to function in and control that world. They must become informed policy makers and consumers; they must cope with change and ambiguity; they must become self-directed learners, risk takers and problem solvers." (House, 1985, pp. 104 - 114)

Examples

Informal resources are available from a large variety of sources. Bybee and Bonnstetter (1987) report that the resources most often used, in order of importance, by science teachers include: journals and magazines, science textbooks, teacher guides, newspapers, source/methods books, educational modules, local curriculum guides, science newsletters, professional meetings, and other teachers. The most important sources cited are print materials.

Resources are available from a vast array of sources. The January 1987 issues of *The Science Teacher* contains the "NSTA Supplement of Science Education Suppliers 1987." Some publishers have special sections in the texts which deal with STS topics.

Recommended Actions

Change is needed on four fronts. First, integration of the pre-service studies of science teachers to develop a stronger *academic background* in the relationships between the disciplines, integrated-STS curriculum implementation approaches, and critical thinking skill instruction.

Second, one emphasis for the education of teachers should focus upon implementing *teaching approaches* to develop the K-12 students' comprehension of the scientific, technological and societal issues. Third, seriously look at strengthening the *in-service opportunities* and graduate programs offered to include courses and seminars which provide specific guidance and materials for implementation.

Lastly, each of the above actions would require modifications and improvements in the relationships between the colleges of education, the science disciplines and other education agencies. The establishment of semi-autonomous centers would be appropriate to conduct the work, develop contacts and provide networks.

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SCIENCE, TECHNOLOGY AND SOCIETY AS EXPERIENCED THROUGH CHILDREN'S LITERATURE

Carol M. Butzow and John W. Butzow

There are many practical reasons for starting STS instruction in the elementary school. Young children are naturally curious and often choose science as the favorite subject (Stake and Easley, 1979). The self-contained classroom which predominates in most schools lends itself to the integration of various disciplines, as children are not changing rooms for each subject. One teacher is generally in charge of the majority of the instructional day for that class and could plan units based on STS.

On the negative side, research indicates that elementary teachers still view science as one of the weakest links in their professional preparation, and consequently do not give it priority as an area of instruction. The majority of teachers mention lack of time as the major reason for not teaching science, with the result that time allotted to science instruction continues to decrease (Gates, Krockover, and Wiedermann, 1988).

One of the easiest methods of including STS instruction in the elementary curriculum is through the use of children's literature. Language arts, reading and literature are not only areas of great strength for many teachers at the primary level, but up to half of the ordinary school day is usually allotted to reading and language arts. By integrating STS units into the language portion of the day, time is not taken from the reading period. The result is actually the reverse. Reading and writing will be continually taught and emphasized, but in the meaningful context of science, as well as social studies, math and the arts. Various disciplines can be viewed in relation to the total society in which the child lives and not in the isolation of the classroom.

This method of using fictional children's literature as a basis for STS instruction can begin as early as kindergarten. Picture books would be the most common source until about grade 3, although many of these works could be enjoyed by middle school youngsters. Only the complexity of the activities would increase. For example, Mike Mulligan and His Steam Shovel by Virginia Lee Burton illustrates several of the problems of a rapidly changing society. In this book, the steam shovel becomes outdated by more modern equipment. A child suggests an alternative use for the steam shovel as a heating plant for the town hall.

Themes of change and obsolescence are expressed in the text. Activities might range from observing simple hand tools like a can opener, for younger children, to building a working steam shovel from plastic blocks for older children. Young children might visit a hardware store and describe, in words, the machines they have seen; older children could write sequential directions for operating various devices. Finding the sources of heat from the school building, experimenting with simple machines or even interviewing a steam shovel operator can give much more insight into the concepts found in the book. To expand on the societal issue of old age, additional works on how people grow old can be added to the unit - e.g. Nana Upstairs and Nana Downstairs by Tomie dePaola and I Know An Old Lady by Charlotte Zolotow.

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By using books which have a strong story line and are of interest to children, facts and ideas are presented as part of the world which they know or can perceive. Knowledge acquisition is not equated with ingesting isolated bits of information which are never conceptualized, and are therefore quickly lost. By dealing with an issue such as obsolescence as it relates to society, children realize that objects (and people) move, work and grow older. Change is one of the most constant factors in their lives and its influence will continue to accelerate as the amount of knowledge available to mankind continues to double every few years.

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STS HIGH SCHOOL MODULES FROM THE DEPARTMENT OF DEFENSE DEPENDENTS SCHOOLS

Dennis W. Cheek

The Department of Defense Dependents Schools (DoDDS) is the seventh largest school district in America serving over 160,000 students in 21 nations where U.S. Armed Forces are stationed. DoDDS has produced a series of eleven modules in STS suitable for a year long course or as free standing supplemental materials.

The Project began with a Research and Innovation proposal by Kent Rossier, Science Coordinator for the DoDDS-Germany Region in 1983. DoDDS in Washington, D.C. agreed to the proposal and a budget of $125,000 was approved. Kent Rossier was appointed Project Head, assisted by Dr. Faith Hickman, then of the University of Colorado, Dr. Joseph Piel of SUNY, Stoney Brook, and Dr. William Ritz of California State University, Long Beach. Fifteen DoDDS teachers assembled on June 17, 1985 at Weisbaden, West Germany to begin drafting materials.

Unlike some high school level STS materials currently on the market, DoDDS' course is laboratory-based. Over 50% of each module consists of hands-on activities. Students are encouraged and required to collect data from their local areas, perform analyses of suitable complexity, and do something constructive with the results. For example, students studying extinction and conservation efforts are required to study a local species endangerment problem and educate others to promote effective action. Specific common strands of process and action skills that each module contains in varying degrees are listed in the chart below by module title. High numbers indicate greater emphasis on that particular skill.

Designed in a modular format to increase flexibility and enable teachers to select suitable topics, the materials are in a notebook format so that materials 'discovered' locally can be inserted. Ten preliminary draft modules were tested in classrooms in SY '85-86. A smaller writing team assembled in the summer of 1986 in Germany to revise all modules for a full year pilot in twelve high schools in SY '86-87. Participating teachers and students filled out evaluation forms for each module used.

Seven writers reassembled in the summer of 1987 in Germany to make final revisions. A Teacher's Handbook was also produced containing summaries of each module, lists of helpful resource organizations and media, etc. The entire set of materials has been edited by Dr. Faith Hickman, currently with the DoDDS Atlantic Region. A brief look at each module will give a flavor of the range and type of topics covered.

Always Room for One More? focuses on population dynamics including world population trends, growth rates, distribution patterns, life expectancy, birth control policies, family trends, and personal decision-making in regards to population issues.

The detection and treatment of genetic conditions such as cystic fibrosis and the design of prosthetic devices to prolong and/or improve the quality of life are introductory topics in Biomedical Technology. Students study mechanisms of heredity, techniques of

COMMON STRANDS IN STS MODULES

	Design lab/field work	Gather/generate data	Interpret findings	Encourage healthy skepticism	Distinguish science/non-science problems	Identify real STS problem locally	Take action on STS issue	Separate fact & opinion	Learn specific decision skills	Identify values influencing behavior	Describe consequences of decisions
ALWAYS ROOM FOR ONE MORE ?	2	3	3	3	1		1	1	1	3	2
BIOMEDICAL TECHNOLOGY	2	4	2		1	1		2	1	4	4
ENERGY	3	3	2		1				1	1	1
EXTRA-TERRESTRIAL		1	1		2			1		3	2
A HEALTHY BALANCE	4	4	2	2	1	1	1	1	1	2	2
LIVING ROOM	4	5	5			3	2		2	3	1
TOO GOOD TO LOSE !	1	1	2		1	1	1	1	1	4	2
TRANSPORTATION	3	3	4	2	2			2		4	2
WATER & CIVILIZATION	5	5	1	1	1			1		3	2
YOUR MONEY, YOUR CHOICE	4	6	6	4		2	1	2		2	
BRIDGING THE GAP	3	4	4					2	5	1	4

prenatal diagnosis, evaluate their own circulatory fitness, explore ethics issues, and exercise responsibility in making decisions for another's life in a simulation.

Students of Energy trace energy back to the sun, measure energy in food, calculate efficiencies of building materials conversions, and analyze selected local, national, and international energy policy making.

Design of a space colony for 1994 is the topic of Extraterrestrial Settlements. Small groups tackle tasks like determining possible uses for such a station, calculate the risks and costs involved, draw up social rules for this micro-society, and solve problems of life support, materials procurement, and transportation.

A systems approach to health is the focus of Maintaining a Healthy Balance. Students consider chemical equilibrium and osmosis at the organismic level. The school is the focus of in-depth scientific analyses as students study this interactive system and recommend improvements. Societal issues are introduced through a triage simulation in a health care facility.

Living Room explores biological, cultural, social, economic, political, and physical aspects of living space. The problems of urbanization and the automobile are juxtaposed. Students use process skills to collect and interpret evidence related to the human use of space and hone their decision making capabilities through real and simulated exercises in the establishment of public policy on space allocation and land use.

Endangered species and conservation efforts are the focus of Too Good to Lose. Food webs, the effects of pesticides, loss with attendant effects of habitat, the role of human beings in the ecosystem, and changes in whaling technology on whale populations are studied. A local species endangerment problem gets students out in the field for critical and relevant data collection and analysis.

Transportation places an emphasis on physical facts that influence design and safety features of means of conveyance. Model bridges are constructed and tested. A car is selected for possible purchase after careful analysis of all relevant features. Cars of the future are designed and three cities' unique transportation systems and problems are compared in an effort to solve a local problem.

Water and Civilization introduces students to how water management technology has caused or allowed social change throughout history. Contemporary water related social, scientific, and economic problems are also examined. A water policy is developed to distribute water to the area of southern California, a shaduf is constructed and data collected on its operation and efficiency, and water policies within ancient and modern societies are compared and evaluated.

Making students wiser consumers is the goal of Your Money, Your Choice. Unit pricing data is gathered, products are tested in the laboratory, advertising and labeling are analyzed, packaging is classified and compared, and environmental and economic impacts are inferred.

Bridging the Gap introduces students to seven formal decision making techniques within the context of a class competition in bridge building. This module is recommended as the starting module for a year or semester course. The skills taught can be transferred to other problems and issues in succeeding modules.

Preliminary feedback from first time teachers this school year in Germany has been positive with few reported problems. Eighteen high schools are using the materials in semester or year long courses with other schools using one or more modules in existing traditional courses. A copy of any one module mentioned may be obtained by request in writing to Mr. Ken Rossier, Science Coordinator, DoDDS-Germany, Box 5904, APO, NY 09633. Please state a rationale for your request. Distribution on a wide scale was not budgeted in the proposal so only justified requests will be honored.

Formerly with the Department of Defense Dependents Schools (DoDDS) in Germany, Dennis Cheek served as principal author of the STS module "A Healthy Balance." At present he is a Doctoral Student at The Pennsylvania State University, 117 Willard Buildng, University Park, PA 16802.

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THE EMERGENCE OF TECHNOLOGY EDUCATION: ITS POTENTIAL POWER

Ronald D. Todd

This paper is founded on several major assumptions related to the potential of technology studies including the following: (1) "Technology" remains a concept of multiple and mixed meanings. (2) A great deal can be learned from the work of colleagues concerning technology education and technological literacy both nationally and internationally. (3) The study of technology provides opportunities for introducing real-world activities and concerns to students, and (4) The active engagement in real-world issues through the hands-on study of technology can make radical changes in what and how students learn and the very nature of schooling.

Meanings of Technology

Technology will have multiple meanings because of the different perspectives taken by individuals and groups as they approach the arena of activity they think represents technology. Conversely the intended involvement and use that a group sees in technology will determine its priorities and perspectives. The following proposed meaning for technology comes from a perspective that intends to clarify what is educationally important about technology. Technology as taught through technology education would be the study of the nature of adaptive systems to include their basic elements (tools, materials, energy, information, processes and humans); the growth of those systems; the use of knowledge and technical means in solving practical problems; and the impacts of these elements, systems and activities on individuals, society and culture. Further, technology education is seen to include an intent to create better solutions to practical/real problems and issues.

A great deal of ambiguity also exists in definitions of the nature, form and purpose of technological literacy. The ambiguity is there by design. Historically linking the term "literacy" with an academic discipline, such as "scientific literacy." was for political rather than educational purposes (Todd, 1985, and Waks, 1986). Who can argue with the cry for literacy? Who can translate that cry--that slogan--into educational practice? As a slogan technological literacy is having an impact on schooling and those who influence schooling. As a viable educational construct, however, technological literacy may be marginally useful and inherently inadequate.

For the past several years technological literacy--the slogan--has guided some initial and exciting efforts toward instituting curricular changes. Lacking clarity, technological literacy has become an ambiguous goal rather than a program or construct. Unfortunately only a threshold goal of awareness has been established. Consequently many of the emerging programs tend to engage students in a detached study of technology. Roy (1986), however, suggests a need for a deeper understanding and study of technology and has identified three levels of technological literacy. The three levels include Technological Comfort, Competence and Control and are represented by the symbol TC3.

A different construct built upon similar concerns but focusing more upon informed technological decision-making was developed by Todd (1986) and is presented in Figure 1.

	LEVELS	TYPES OF KNOWLEDGE	COMPETENCE
I	Technological Awareness	Knowledge That	Understanding
II	Technological Literacy	Knowledge That	Comprehension
III	Technological Capability	Knowledge That & How	Application
IV	Technological Creativity	Knowledge That & How	Invention
V	Technological Criticism	Knowledge That, How & Why	Judgement

Figure 1: A Taxonomy of Capacity for Technological Decision-Making

The lower level of the taxonomy does, in fact, deal with the awareness and understanding of technology. As indicated, competence at this level would require little direct involvement in the use of technology and would represent more accurately a study "about" technology. The second level of the taxonomy moves beyond simple understanding and includes comprehension and literacy. Technological literacy, therefore, implies additional insight and knowledge than resides in technological awareness.

The higher levels of the taxonomy propose a different capacity and move beyond knowledge that to knowledge how and why. For many concerned with teaching technology additional emphasis is placed on the next level of capability and application. The shift to the use and application of technology underscores the need to help students build upon the lower level competencies and become actively engaged in learning what technology is and how to apply it in the solving of practical problems. Still others are more interested in the creativity and invention potential of technology.[1] The desired competencies at these levels use all the lower level competencies as a foundation for technological creativity.

The final level of the taxonomy of criticism and judgement is perhaps most important for all students. At this level attention is given to the knowledge required for the questioning and criticism of technology. This is not to be seen as the data- or experience-poor approach to technological criticism in which anyone can engage. Rather, it is the serious study of technology to provide insights into the problems faced by individuals who engage in technological activities. Experiencing both success and failure in technological innovation is essential to gain insights into some of the problems and pitfalls of technological progress. Such insights are, in turn, essential for identifying the short- and long-term problems and consequences of technology on individuals, the environment, society and culture. The cumulative competencies should help our students become better decision makers regarding technology-its products, its problems, its development and its impacts.

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[1] In the U.S.A. much of this effort falls outside the regular school day often in the form of creative competitions such as the Odyssey of the Mind (O/M), the Miniature Innovation and Invention in Technology (MIIT) and others. Only recently has the profession of technology education begun to tap the potential of these types of activities. In the United Kingdom, however, technology related education generally, and the craft, design and technology effort specifically, places considerable emphasis on this type of learning and capacity.

Unfortunately the meanings of technology, and consequently technology education and technological literacy, remain somewhat ambiguous. At this point in time no common definitions and certainly no common programs of technology have been adopted in any country let alone world wide. Common programs are not necessary or even desirable. Common meanings and definitions, however, are essential. The meanings ascribed to technology may take on several different forms. One framework to clarify the meaning of technology as a school subject, drawing upon the work of Deforge and others (1972), was developed by Todd (1985). As shown in Figure 2. these meanings of technology ranged along a continuum between specific to general and included technology as skills, motivation, a subject in its own right, an end in itself, a guiding theme and a perspective.

TECHNOLOGY AS

SKILLS	MOTIVATION	SUBJECT IN ITS OWN RIGHT	AN END IN ITSELF	A GUIDING THEME	A PERSPECTIVE

Specific *General*

INSTRUMENTAL
NATURE
OF TECHNOLOGY

INFLUENTIAL
NATURE
OF TECHNOLOGY

Figure 2: The Forms of Technology

The six forms of technology as a school subject include:

1.technology as skills particularly with emphasis on tool skills;

2.technology as a form of motivation that uses hands-on and project activities to add interest to other subjects;

3.technology as a subject in its own right;

4.technology as an end-in-itself that provides conceptual frameworks for integrating content and skills learned in other subjects;

5.technology as a guiding theme that provides organizers for what students are to learn; and

6.technology as a philosophical perspective that includes a set of higher-level problem solving skills (Todd, 1985).

The different forms of technology reside on a continuum with the more specific forms representing the instrumental nature of technology and the more general forms its influential nature. The more instrumental forms of technology serve as the direct "means" through which we affect technological change. The more general forms of technology represent the influence that technology has on us. The influential nature of technology represents the indirect "effects" that technology has on the nature and behavior of those engaged in technological activities

The framework presented above is intended to facilitate disciplined discussions about technology, technology education, and technological literacy. Such discussion would move away from using the terms as slogans, missions or causes and turn to the difficult task of providing direction and meaning to the implementation of technology as an essential experience for all students for the integration of their learning and knowledge.

Integration of Knowledge

The phrase integration of knowledge suggests there may be another state on knowledge, namely, disintegration. In the standard experiences of schooling, disintegration appears to be the rule rather than the exception. The curriculum is shaped by teachers who have specialized in a limited number of disciplines. Few of us as educators have been prepared to draw upon more that two or three different disciplines. Yet, only recently there has been a renewed interest in interdisciplinary learning, which implies, or perhaps requires, the integration of different bits of knowledge into some meaningful unity or whole. It is within this context and need for the integration of knowledge and learning that some of the hidden potential of technology education begins to emerge.

To understand some of the potential power of technology as an integrator of knowledge, it is important to underscore a premise of technology stated earlier, namely the intent to create better solutions to practical/real problems or issues. A few vignettes of practice in teaching technology should be helpful at this point. Consider, for example, the richness for integrative experiences that resides in the combining of drama, writing and technology classes to have the students interpret and stage available plays as preparation for moving on to creating, designing and producing their own plays. This is not a new activity but the inclusion of technology, designing and implementing the stage settings, the lighting, the sound control and even the video recording introduces exciting opportunities for integrating what the students are learning. Other examples could include: pollution studies of the school, home and community by merging biology, psychology and technology; museum or science/technology exhibits that brings together classes in science, technology, history and art; local archeology projects that draws upon science, mathematics, history and technology; community service projects that apply what students have learned in art, psychology, social sciences, and technology; and the list could go on and on.

The power resided in integrative learning is enhanced by engaging students in activities for creating better solutions to real and practical problems and issues. Creating better solutions require students to put what they know into practice-not a common experience within our schools.

The application and integration of knowledge through real activities has exciting and untapped potential for placing technology at the core of the curriculum for all students. Part of that power resides in using and teaching technology cooperatively with colleagues from other disciplines. The cooperative teaching of technology can help us create new perspectives and insights into what technology is, how it relates to other disciplines, how to use the work of students for considering the consequences and impacts of technology. activities. Insights gained from such integrated learning will be essential for enhancing the technological literacy of our students and for laying the foundation for students to move to higher levels of technological capacity.

In order for us to capture the potential of technology for integration of learning and knowledge it will be essential for teachers and students to learn new educational behaviors as they seek to create better solutions to real problems and issues. It will no longer be appropriate to think about teachers only as teachers and students only as students. The lines between teaching and learning will continue to blur especially as computers and other media-technology devices become more available in the classroom and laboratories. We can already see students becoming teachers and teachers becoming students. For most of us who have experienced that role reversal it has been very rewarding, particularly as students begin to experience some of the rewards of teaching and as both students and teachers begin to experience some of the delight of cooperative learning.

The Power of Technology Education and Technological Literacy

There is a very important symbiotic relationship among the various efforts to include technology as a content area within the school curriculum. Each of these efforts have something to add to the overall experience for students. Each, however, is inadequate to the educational task that lies ahead. There are major obstacles to overcome if we are to see technology included as an important, even essential, part of the curriculum. Educational innovation and change is not for the faint-hearted nor for the loner, whether individual or association. In essence the totality of our efforts could be more than the sum of our individual contributions. Such a synergy is possible if ways are found to integrate and consequently maximize the work of those involved. For example, many of the programs and their participants feel very comfortable with engaging student in important and interesting discussion about technology and its impacts. Others place more importance in engaging students in the direct use and study of technology. Others yet have found it more productive to have students engage in problem solving and design activities while others see technology as the media through which new content and skills can be taught. Imagine how vital the learning would become for students if they could experience all these variations of technology throughout the curriculum.

The results and effects of the enriching schooling through real experiences from technology would shake education to its foundation. Students would see science in action through activities that add meaning to abstract concepts and isolated incidences. Math would take on a new dimension. Building upon practical activities designed to introduce concrete examples, math through technology would help students experience the beauty of math in practice as well as laying the foundation for appreciating math for math's sake. Discussions on the impacts of technology would grow out of actual student experiences rather than representing a sanitized version of someone else's experiences. the integration of approaches through individualized activities would result in an increased ownership of learning by the students.The introduction of these practical aspects of learning through the study of technology, therefore, would change what goes on in the schools and how teachers and students interact, with students often becoming the teachers and teachers becoming learners. By using the integration potential of technology studies, the cry for relevance, meaning and engagement in learning would finally be heard. It is to these potentials, these ends, these changes that our efforts must be directed.

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INSTRUCTIONAL OUTCOMES CHANGE WITH S/T/S

Robert E. Yager

S/T/S ideas and approaches have been introduced in classrooms of 300 teachers in grades 4 through 9 in Iowa since the 1985-86 school year. Assessment of results of S/T/S instruction has been central to the effort which has been supported by the National Science Teachers Association, the Iowa Utility Association, the National Science Foundation, and the University of Iowa. Some of the emerging results demonstrate the advantages of an S/T/S focus for school science.

Students are better able to apply information, to relate information to other situations, to act independently, and to make decisions. Nearly 1,000 seventh and eighth grade students were tested over a three year period in specific schools where there were students in one class who had experienced science in a traditional manner and others in another class who experienced their science with an S/T/S focus. The assessment efforts were all characterized be students being asked to perform in ways consistent with course objectives. Five areas where students in S/T/S courses excel illustrate the power of S/T/S efforts for those valuing such student skills/learning outcomes. These areas include applications, creativity, attitude, process skills, and science concepts. The following percentages of students enrolled in the two types of science courses illustrate the superiority of S/T/S teaching when asked individually to perform following a given experience/exposure.

Percentage of students who can:	Enrolled in typical science class	Enrolled in S/T/S class
Demonstrate the use of information in new setting	25	81
Relate two phenomena to a new situation	18	66
Identify related but divergent questions from a given situation	17	83
Choose relevant information to use in solving a problem	26	91
Choose appropriate action based on new information provided	35	89

Utilizing some of the affective items from the Science Assessment of the National Assessment of Educational Progress provides a means for contrasting student attitudes after experiencing science in a traditional classroom vs. one focussing on S/T/S. Reports from a thousand seventh and eighth grade students contrast the situation:

Percentage of Students With Specific Perception:	Students Enrolled in School with Typical Science Program*	Students Enrolled in Schools with S/T/S Science Program
Science classes are fun	40	81
Science classes are boring	31	14
Science classes make me curious	24	71
Science classes help me make decisions	31	63
Science teachers like my questions	48	88
Science teachers admit to not knowing	22	74
Information from science classes is useful	69	81
Science is a favorite course	11	22
Science is least favorite	19	6

*Figures approximate pretest scores in schools moving to S/T/S approaches as well.

There are many facets of creativity and many instruments that have been developed to assess in this domain. One aspect that has received attention in Iowa is concerned with questioning both in terms of quantity and quality. Some of the differences in abilities of seventh and eighth grade students following traditional science instruction and S/T/S instruction include:

	Average Number in 30 Traditional Classes	Average Number in 30 S/T/S Classes
Number of questions generated after same situation is presented	580	1160
Number with unique questions (less than 10% with similar ones in given class sample)	21	105
Number who can distinguish between cause and effect	216	643
Formation of unique explanations to a specified situation	51	342
Design of unique tests of ideas generated from a given situation	28	405

Process has been a dimension of science which has received major attention in science education for 50 years. Unfortunately, most of the attention has been lip-service with little research evidence to demonstrate that science teaching resulted in students who possessed better science process skills than they had without instruction. Again, S/T/S efforts have produced students better able to perform basic science processes. Process items in each area of the 13 processes of science identified by AAAS for its Science: A Process Approach program for K-6 use have been developed over a five year period. Teachers choose items for each skill most appropriate for their respective age levels. Results for a given school were secured from items selected by teachers as appropriate for their seventh and eighth grade students. Following is information that demonstrates the contrast for seventh and eighth grade students in 30 class groups:

	Science in typical classes	Science in S/T/S classes
Selecting best experimental procedure	24	52
Hypothesizing	18	63
Comparing & differentiating	31	84
Measuring	33	91
Using numbers	40	89
Predicting	19	71
Drawing conclusions	24	82
Controlling variables	21	63
Communicating	38	86
Inferring	19	74
Interpreting data	31	88
Classifying	26	87
Observing	30	84
Using space/time relationships	12	51

Acquisition of information has been a primary focus for school science. Some have feared that an S/T/S approach would result in less information. Miller selected key concepts for his national studies of science attentiveness (Miller et al, 1980). Other science concepts were from third grade science textbooks for use in a series of follow-up studies in Iowa (Yager & Yager, 1985). The following listing demonstrates that such a fear is not well-founded with respect to 8 concepts studied in 30 schools involving a thousand seventh and eighth grade students:

	Students in typical Science Classes	Students in S/T/S Science Classes
Volume	75	65
Organism	67	71
Motion	65	62
Energy	54	45
Molecule	54	48
Cell	46	43
Enzyme	24	31
Fossil	54	48

Studies concerning student retention of information over time have not been accomplished in any sustained way. Everyone is willing to concede that much of what students learn for examinations is forgotten soon thereafter. Some of the S/T/S efforts have been too new to permit follow-up studies over the span of several years. However, since S/T/S students are so much better at making applications and connecting experiences to others, there is every indication that the information students possess is indeed knowledge, i.e. information that is useful. If information which is mastered can be used and if it has real meaning for the learner, there is every reason to believe that S/T/S instruction is providing a much better experience in the information domain. The S/T/S effort with 300 teachers in Iowa has provided specific results with the students they have touched that demonstrate the power of S/T/S as a primary focus for science teaching/learning.

Some have argued that S/T/S efforts in schools will fail because they do not affect standard test scores--or that the claimed advantages cannot be measured. The evaluation of Iowa students seems to refute these concerns. To date there have been no significant gains with respect to student acquisition of information. However, the improvement with respect to student attitude, the ability to use process skills, growth in terms of some features of creativity, and the ability to use information in new situations are impressive and positive advantages of S/T/S instruction for even the most hardened skeptic. As more teachers are involved, as more time is spent in given courses and over grade levels, and as long term studies give students the chance for even more impressive results arising from S/T/S instruction, specific advantages for S/T/S instruction are likely to be even more impressive. In fact, the assessment information may be as exciting for many as are the positive student, teacher, and parent testimonies which are first produced. Testimonies tend to wane; however, real evidence exists for all to see and to interpret.

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STS AND SECONDARY EDUCATION

Jane Abbott

As many of you probably know, Dr. Paul Hurd has been leading the way in Science, Technology, and Society programs far longer than anyone else I know. It is a real honor for me to be sharing the podium with him. One of the programs I shall be discussing today is the Search for Excellence in Science Education (commonly known as SESE), sponsored by the NSTA. This was a committee where we were assigned a lot of homework! As you can imagine I enjoyed reading the many articles by Dr. Hurd, such as the one co-authored with Kahle, Yager, and Bybee, also speaking at this conference.

The SESE Committee is one of the most rewarding committees I have ever been on -- and one of the most demanding. We read publications from the "Nation at Risk" to "Gaia" by J.E. Lovelock, and just about everything in between.

The members of the committee, chaired by Emmett Wright and Fred Blumenfield, felt they had a responsibility to provide a structure for the "development of scientifically and technologically literate citizens capable of functioning in the decision-making process of a democracy." We wanted a "holistic-hierarchical approach to teaching biology." We studied past research on science as a way of knowing and wanted our focus to de-emphasize scientific fact and utilize the facts to "document a way of thinking." Since the well-being of both society and the individual are best served by a concern for the welfare of the biosphere our major hierarchical organization was: biosphere - society - individual.

Three NSTA publications we studied which are still useful in developing strategies for successful teaching of biology in a technological world with an emphasis on social issues, personal needs, and career awareness are: "Science-Technology-Society: Science Education for the 1980's; "NSTA Position Statement" (1985), containing a list of 13 criteria required for the development of a scientifically-technologically literate citizen; and "Standards for the Preparation and Certification of Teachers of Science, K-12 (1984).

We prioritized our goals with the first being: "to provide a biology program for all students that addresses the present and future needs and interactions of the biosphere, society and the individual." We feel that the human race needs the biosphere although the reverse would not be true, especially in such individual centered decision making as might lead to Hardin's "Tragedy of the Commons" (1968). The second goal stresses the value of classrooms-without-walls; to help students recognize the "fragile balance and interdependence existing in the biosphere." An awareness of Lovelock's Gaia Hypothesis that our planet might be considered a living system could help us avoid such catastrophes as the destruction of the tropical rainforests and the carbon dioxide loading of the atmosphere. Our third goal is to "provide a biology program for all students which has a social and technological focus for the application of basic and fundamental biosphere concepts and principles." Rachel Carson's "Silent Spring" and Graham's "Since Silent Spring" still represent significant statements. Although we indicated that ethical/moral decisions that arise cannot be left to the scientific community alone, I feel that scientists who have accurate data and knowledge of a subject should stand up and be counted.

We feel that a curriculum should do many things: science should be a process -- to solve problems -- not a mysterious black box, but a creative act, able to use trial and error, and always alert to prove its falseness -- not support an absolute dogma. It is the interpretation of the facts that give them power. We have finite resources and many demands on them. Our curriculum should be such that it encourages active involvement, not passive acceptance. Rather than a formal scientific method, a trial and error approach plus a dash of serendipity could be encouraged.

At the Dwight Englewood School, in Englewood, New Jersey, where I now teach, the members of the science department review a book each month, as we meet for a covered-dish supper in one of our homes. This month it is "The Periodic Table" by Primo Levi. The discussion on this book was lively and led to a new insight by many of us into problems all people face, some more than others, including the students we teach. We have started a similar journal club for the students as an extra-curricular activity.

The SESE Report stresses experimental and experiential laboratory and field trip experiences with many open ended opportunities. We feel that students gain confidence when they develop skills in acquiring, utilizing, interpreting, analyzing and evaluating data. In lieu of a complete reliance on one text we recommend expanded use of community resources. Students who participate in a study and exploration of local, regional, and global biological issues are investing in their own future, and buying into an active involvement in the pursuit of solutions.

When I taught in Maine in a school only a half hour away from the state capital students often testified at hearings and had a well-earned sense of accomplishment when legislation they supported was passed. This was particularly true when we (Maine) passed the toughest oil handling legislation in the country, and later passed the so-called bottle bill against strong opposition. Students were almost unbelieving when the Pure Food and Drug Administration passed legislation banning Red Dye #2 at about the same time they received a letter from a national bottling company denying that the dye was harmful.

The fourth SESE goal is "to provide a biology program for all students that continues the development of creative and critical thinking skills applicable to the decision making process." This goal stresses the same problem solving skills needed in every day life and helps students recognize the relevance of science to their lives. Ethical/moral problems are becoming daily occurrances. Just last week New Jersey declared surrogate motherhood for money to be illegal. Newspapers and magazines provide an unlimited source of information.

It is important to work with societal issues through an integration of diverse ideas from the sciences, technology and the humanities, and to be involved in professional organizations, community activities, and the publication of innovative ideas. Some of the standards for the preparation and certification of secondary school science teachers set by the NSTA are: evidence of studies concerned with the interrelationship between biology, technology and society; service as a role model providing opportunities for the sharing of competing ideas with students; creation of an environment for the development of positive student attitudes towards the role of science in their world; and recognition of the inherent worth and differences of individual students. Visiting and exchange teachers are another option to provide a new perspective. Students, teachers, and the school system would benefit if teachers were encouraged to become involved frequently in exchange programs.

A significant area in which the NSTA and NABT have been working recently has been in the development of a standardized biology test for high school students. One of our aims was to influence textbook publishers away from a rote memorization approach by putting higher level questions in our test and also to include science, technology and society as one of the major theme areas expected to be in any biology course. From the response of schools throughout the country to the test and the many copies sold we feel that we shall be having an impact on biology curriculum. We were, incidentally, pleased with the reliability of our first biology test, which was a .91 on both Form A and Form B of the test.

One aspect of the technological literacy conferences that impresses me is the large number of international representatives. This summer I am taking a group of biology teachers to China to interact with our counterparts in China. I am absolutely amazed at the response I have had from biology teachers in the United States, and even Canada and Australia. I guess we are all ready to Get-Up-and-Go. Many teachers are receiving financial support from their schools and/or state department for financial help on this trip, and quite a few are obtaining help from industry. Industry is a largely untapped educational resource. At one time when I had a foundation grant for science enrichment in my high school, every industry in town contributed money toward equipment and supplies to supplement it. Once, following the gift of an electric pH meter a group of my students wrote an audio-tutorial instructional system for the industry so that any employee of the industry could sit down and learn without help how to use the instrument. Such cooperative endeavors could help students see the relevance of education.

Quite a few years ago, at the request of Dr. Joseph Novak of Cornell, I participated in teaching an AIBS short course on concept mapping. Recently, we have all been hearing a lot more about concept mapping. Recently, I was delighted to note that the most recent edition of the BSCS biology text, "Biological Science" (Green Version) is written with concept mapping as a central methodological theme.

Probably one of the major causes of science antagonism in many secondary schools today is the required rote learning, the memorization of facts: formulas in physics, reactions in chemistry, and classification in biology. Cognitive psychologists today stress the importance of making connections, and of building on what you already know -- subsumers as we used to call them at Cornell. An example given in the Green Version is making evolution meaningful to the student by discussing it in the context of genetic variation and selection pressure, but only after relating it to height variation in the context of basketball players.

The next step is a method of structuring the connections in a hierarchy which places broad, general principles at the top and more refined details at successively lower levels. Some topics lend themselves more readily than others to this hierarchical arrangement. The biosphere, for example, can be divided into living and nonliving components, with the nonliving further divided into matter and energy, etc. At this point connections can be made with the living component since animals eat plants which are made of matter that contains energy. Students and teachers can learn to develop hierarchical associations by making concept maps.

It is the tying of concepts together with each other and also with knowledge previously gained, structured as a hierarchy, which gives meaning to the students, and helps to make them successful problem solvers. Students who have had experience creating concept maps tend to be more successful learners. I found when I used this technique with my students that they resisted the assignment at first but soon became very comfortable with it. Recently, I was asked what I felt was the most pressing need in secondary education, to which I replied that certainly one need is for teachers to be given time to follow through on the many exciting ideas they obtain at conferences which they would love to try but too many other demands on their time prevent them from getting a start.

Another aspect of concept mapping that I like is that the student is expected to be responsible for his own learning by taking an active role. By asking himself continually such questions as: "Did I understand what I just read? Can I make it relate to what we read last week or with something else we have studied? Can I make a concept map of it?" This technique is the making of an active learner who will, hopefully, by his better understanding and reinforcement, have converted this material from short term to long term memory -- and have a much enriched understanding of the concepts involved. Students who have an in depth understanding will be the ones who are able to apply what they have learned in one context to new and unfamiliar problems and will become better problem solvers in the process.

As a teacher, I find the concept map can give me quick feedback of a diagnostic nature so that I can determine with a quick glance how well students understand a particular assignment. I see a change from linear, traditional textbook learning to hierarchical learning with understanding.

Skimming is another technique stressed in the BSCS book. If a student is interested in a topic he will read with understanding, as he now has an overview of the material. It can be compared to flying over a particular region in an airplane. I can really relate to this recommendation for I am a commercial balloon pilot and thoroughly enjoy the overview, or grand picture, I get while flying over unfamiliar territory. A major aspect of skimming, however, is that the student skim the material quickly, with only 3 or 4 seconds to a page and then jot down just a few ideas. He can skim the material several times adding a few points each time and relating one word or idea to another. It is, however, important to move right along and resist the tendency to slow down to read every word.

I teach a speed reading course where the students are urged to develop the habit of skimming fast and remembering just bits and pieces which they will jot down. They then work with a partner and ask each other questions. It is amazing how much one remembers when the memory is jogged with questions.

Another technique used in the Green Version is to have the student write his own hypothesis about information he has read. For example in studying photosynthesis the student is told that chlorophyll B absorbs more light in the blue wave lengths than chlorophyll A so is more efficient in shady areas. He is then given a chart showing a forest succession which shows that oak seedlings can grow under pines but not the reverse and asked to state a hypothesis to explain it. (Oaks have more chlorophyll B).

At the advanced placement biology level my favorite book of all time is Campbell's "Biology" with a study guide by Martha R. Taylor, published by The Benjamin/Cummings Company. Taylor utilizes concept mapping in the study guide and describes it as a "hierarchical exercise designed to help students own their knowledge rather than resort to rote memorization."

The chapter on metabolism has a heading: "Structure your knowledge" which suggest the following to the student: "This chapter introduces many complex ideas concerning the thermodynamics of metabolism. Take the time to organize your understanding of small chunks of this information and then try to integrate these pieces into your picture of the energy transformations taking place within the cells of living organisms." Students are instructed to:

1. "Create a simple concept map concerning energy: its definition, examples, and the first two laws of thermodynamics.

2. Develop two separate concept maps, one for enthalpy and delta H, and one for entropy and delta H. Then try to combine these two maps under the broad umbrella of free energy and delta G. The value in this exercise is for you to wrestle with and organize these concepts for yourself. Do not turn to the suggested concept map until you have worked on your own understanding. Remember that the concept map in the answer section is only one way of structuring these ideas. Have confidence in your own organization."

One of the directives for "Excellence in Science/Technology/Society Programs" is to "foster skills in testing validity of arguments and explore examples of seemingly sound scientific reasoning that led to erroneous conclusions." The talk by Dr. Herbert Their and others from the Lawrence Hall of Science considered new types of evidence and the valid, and no so valid, conclusions which could be drawn from them. For example, an infrared photograph and a demonstration of toys followed by a videotape of the same toys being used in space were shown. We learned that it is important not only to collect evidence but that much can be gained from analyzing it -- as is done for extended periods following space exploration.

Another STS instructional strategy is to motivate students to explore emotions and values in relation to the data of specific events. A biomedical conference I attended at the World Trade Center in New York last June explored many aspects of medical ethics. I was fascinated to hear doctors, Orthodox Rabbis, Catholic sisters, and lawyers debate the various aspects of medical ethics. We should be exploring the same in our classes on STS topics. A few of the medical dilemmas faced by doctors include:

When to pull the plug? Who determines when meaningful life continues? Are there differences between withholding and withdrawing treatment? Are we paying an enormous price for the extension of life at the margins since eternal life is possible only through genetics? Why do we spend $2,000 per person per year on medicine in the U.S. even though it is more than the income of most people on earth? Does the return on the dollar justify the diversion of those dollars from others? Should we allow death to come when it has announced its arrival? Should we have basic health care for the many or high tech for the few? When AIDS patients can't pay the cost of medicine should we provide it to save their lives a couple of weeks? A doctor commented that about half of what he tells his patients is wrong and that he does not know which half it is. A Catholic nun stated that there are times in keeping with the preciousness of life that one should not provide treatment but allow the patient to die. A Rabbi jokingly said he had walked in an Orthodox Jew and might walk out a philosophical Catholic.

I should like to close with two quotes from Maggie Kuhn, founder of the Gray Panthers. "On my 82nd birthday I resolved to do something outrageous at least twice a week," and "I've been privileged beyond what I could ever merit to be with people like you." Although I don't think we should all wait until our 82nd birthdays to be outrageous I do feel that she is on target in her reference to being with people involved in Science, Technology, and Society.

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SCIENCE, TECHNOLOGY, AND AT-RISK STUDENTS: THE CASE FOR LITERACY IN THE LAB

Kenneth Alston and J. Elspeth Stuckey

At the STS Conference last year, Sheila Tobias spoke of the anxiety and alienation certain students feel about science. She called these students "outsiders," and suggested that they, unlike, "insiders" perceive indominable features of science and technology.

Dr. Tobias' use of the idea of "insiders and outsiders" is interesting because this notion has been used in the field of language education. Frank Smith, a noted scholar in humanities education, speaks of insiders who possess conventional knowledge of standard English and outsiders who do not. He likens literacy to a club whose membership is gained through linguistic credentials. Like Tobias, Smith is concerned to turn outsiders into insiders.

In many ways, analogies such as these are powerful. It is good for us to remember that none of us is born a reader, a writer, or a scientist and that insider-outsider differences can be found in both science and literacy. The power of the analogy wanes, however, as the boundaries of the outsider category widen. Specifically, at-risk minority students--in urban and rural settings--confront more than clubhouse rules. The truth of the matter is that at-risk minority students do not suffer from faulty perceptions of elite membership in the fields of math and science. They face the reality of a near total exclusion from these--and other--opportunities in the world they live in. Thus, as students who see little hope for membership in technological fields, they surprise us little by failing to seek entry.

The response of many of us is not only to feel a strong commitment to resolve problems of exclusion but to implement successful methods within the confines of our institutional structures. How to do this is neither prima facie apparent nor compatible with entrenched structures. This is not to say that major changes cannot be made, however.

We would like to offer a description of the ways two very different institutions have sought to both circumvent and reinvent these structures to address the need for minority participation in the sciences. Moreover, we would like to focus on the one facet of these programs that we believe argues for the greatest eventual success.

The two programs are those at Phillips Academy in Andover, Massachusetts, and Benedict College, in Columbia, South Carolina. The difference between these two institutions might be described as "black and white." Benedict College was founded in 1870 to educate freed slaves. Andover was founded in the mid seventeen hundreds to educate the sons of the New England elite. Today, the annual family income of 75% of Benedict students is under $8,000. The 1985 tuition at Andover was close to $9,500, more than Benedict families make in a year. From this other differences between the schools might be inferred.

In the mid-seventies Andover instituted a program called Math and Science Squared (MS)2. As Andover said in an annual report, "In about 1974 it became apparent to the Headmaster and others . . . that minority students across the country were not being adequately prepared to face the challenges of mathematical and scientific careers." They said, "We cannot allow this to happen."

What can a school do when it can support social commitment with wealth? One thing it can do is create its own club. This is what Andover did.

Andover created a "summer club" of black, Indian and hispanic students from urban and reservation centers across the country. It recruited students from ninth grades in high school and placed them in a graduated, three year summer program of intensive academic work. The students attended classes at least 22 hours a week. They went on field trips, participated in a campus social life, and benefitted from one-on-one contact with counselors, tutors, and teachers. Whereas the attrition rate for the early years was relatively high, it dropped quickly and steeply in following years. Today the number of students who matriculate and go on to college is almost 100%.

Another thing that Andover did for these students was pay for them. In one sense, Andover bought success. The 1984-85 operational budget for the (MS)2 program was $195,660. What happens when schools cannot pay for their students--during the regular year much less during the summer? Can one reasonably expect these schools to offer superior academic training to students? This is a question that might be addressed to Benedict College.

Literacy in the Lab

At the beginning of 1987, Benedict College in collaboration with the Writing Program at the Breadloaf School of English began the Science-Intensive-Feedback (SIF) Project. This project involves high school ninth graders and college undergraduate students. These students meet once a week in a chemistry laboratory to conduct usual, sophomore level experiments. The laboratory itself is but serviceable and the lab manuals for the first semester never arrived so students worked from xeroxed hand-outs. The actual contact time per week was less than three hours, and there was no auxiliary support except for the high school principal, who drove the students from the high school to the college in his van.

The total budget for the first semester of the project was less than $2,000. This project, nevertheless, quickly achieved success, and along with MS2 it is producing at-risk students who not only want to be scientists but who can be.

How can this be done in such wildly different settings with such vastly different means? We are of the opinion that programs like these can work when they have at their center two commitments. The first is a commitment to social reform. The second is a commitment to the integration of science and literacy. That is, we believe that a science laboratory provides a setting in which students cannot only enhance their knowledge of science but can do so by acquiring critical literacy skills at the same time. By no means central to the usual laboratory environment, literacy in the lab provides both for its own improvement and the improvement of science--and society--itself.

Andover accomplishes the integration of science, society and literacy through immersion. During the summers, along with the nine or ten hours in science and mathematics each week and the four to five hours of homework at night, the students spend three hours in English courses. The English coursework is set up in a two-year sequence and emphasizes daily writing, reading, speaking and listening. Students rewrite all of their papers and concentrate on all levels of composition from grammatical correctness to the sophistication of ideas. In addition, many of the science courses emphasize writing. In the third year, "English workshop" is replaced with a course devoted to "the college scene." This is a course in which students investigate college possibilities across the country, write and submit college applications and essays, analyze choices for the future, and discuss the significance of being a minority student on a majority campus.

Literacy and science in the three years of the MS2 program are thus built into each other, and the integration serves to prepare math and science students to move from the curriculum and protection of Andover into the larger, and, admittedly, more hostile world.

A hostile world is certainly one that Benedict must prepare its students for, also, and one that encroaches more on Benedict's ability to function than on schools like Andover or even state-supported public schools and colleges. It is imperative, therefore, that schools like Benedict successfully integrate the goals of science and literacy.

The key to the SIF project at Benedict was the way it set up a communications network. Involved in the project were a college science teacher, a high school science teacher, a humanities coordinator, and at-risk high school and college science students. We decided that the way to achieve learning in science and literacy was to stay in touch at all levels at all times. So, we established continuous, dynamic communication among the parties. We funneled information about the laboratory among teachers, students, tutors, project coordinators, and project sites. We used each others backgrounds as agencies of discourse and clarity. We fought each other over issues of lay language and scientific jargon. We created a community of experts and we learned to value expertise.

The actual procedures were fairly straightforward. When an experiment was conducted, the college students organized the set- up. The high school students assisted by weighing materials, measuring volumes and recording observations.

After each experiment, the students wrote reports. In addition, the college students wrote field notes on the activity of the high school students. This information was sent to the project coordinator who responded with observations and questions. Since the coordinator knew little about chemistry experiments, she often asked for clarification. She would write:

"I do not understand what you said about the Solvay Process. I do not even know what "Solvay" means."

"This lab report is a monument to mediocrity."

"What is the use of paper chromatography of Metals?"

The students would respond. They would write:"

"You are wrong."

"You don't know enough."

Finally, the Aspirin experiment came along and with it, issues that went beyond the test tubes. The coordinator knew what aspirin was. "Did you take the aspirin?" the coordinator wrote. The students wrote back. "Are you kidding? Do you know what aspirin smells like?"

The students were not about to take a chemical they distrusted. The coordinator, herself, was sobered by the idea of seventeen year olds making a commercial drug. Could they have taken the aspirin if they wanted? Would it have killed them? Could they sell it? According to the science professor, students could certainly become proficient aspirin manufacturers. The lab questions had suddenly broadened, and life had walked in the door.

As the project continued, the techniques of communication changed, too. At first, the high school students wrote handwritten letters. The college students did, too. Then, the college students learned to use the single computer in a research lab. By a stroke of good fortune, the high school acquired an AT&T computer. The Bread Loaf School of English decided to fund on-line network time. High school and college students could communicate in 30 seconds. But, on line networks cost money. Students who could communicate speedily also had to communicate effectively. Good literacy became the invention of good science--with some serious after-class bargaining for peer instruction with E-MAIL thrown in.

The results are proof of the project . Intensive feedback is good. The high school students are eager to come to the lab each week, and the college students inquire always about the welfare and progress of the high school students.

There are problems, of course. Today, many, many more minority students live in situations like Benedict than in situations like Andover. Single projects will not accomplish what institutionalized and revitalized science and literacy instruction can bring about. Nonetheless, there are few schools who do what Andover and Benedict have done. Both Benedict and Andover are making it possible for at-risk students to become scientists. The students that Andover sends back to high school and then on to college change the environments they inhabit. The students that Benedict pairs in the lab become responsible teachers and learners whom other students observe. New avenues of interdisciplinary communication open: English and Science faculty speak to each other. Students get used to asking for information. The high school students just asked for a computer course.

It is not the case that some schools should be poor and some rich, some projects well funded and some bankrupt. It is the case that at-risk poor students can become humane, technically adept scientists and science teachers. Right now, we all have to work to make this possible. Presently, Andover has in the works a new summer program to train minority science teachers. Last summer Andover offered a Bread Loaf School of English course to urban high school teachers. Today Benedict College has five Bread Loaf trained future scientists. What they are waiting for is another opportunity. That opportunity appears now to be waiting for them.

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IS THERE A "HIDDEN" CURRICULUM IN STS STUDIES THAT IS SUCCESSFUL WITH AT-RISK URBAN MINORITY HIGH SCHOOL STUDENTS?

Paul C. Jablon and Terry Born

- Most urban high school systems have a reported dropout rate approximating 40% -- higher in inner city areas.
- In these same high schools, students who are attending cut many of their classes at an alarming rate.
- A number of studies show that a majority of youngsters already "dislike" science by the time they reach high school.

These three sobering realities, when analyzed, bring into focus a clear and elementary concept: no matter how well STS units are infused into our present science, social studies or English classes, they WILL NOT BE OF MUCH HELP TO STUDENTS IF THEY ARE NOT ATTENDING THESE CLASSES.

At this point, many of you reading this may be saying, "do you expect me to change the whole school system?" It is our contention that those educators who understand and are concerned with the STS interface are most prepared to make some of the necessary changes in the structure of our schools' curricula and methodologies. It is much more than the interdisciplinary mandates of STS that are needed to counteract the problems inherent in the schools of present day society, but STS's central focus is an essential element.

Urban secondary schools are presently confronted with problems that are multi-dimensional. Peer groups foster negative attitudes towards academic achievement(1). Single parent families create new emotional instabilities for students(2, 3). Television so pervades the lives of children that it leaves them passive, with less linear thinking capabilities and in need of more constant auditory and visual stimulation(4, 5). In addition, they have been exposed to the corruption, immorality and depravity of all aspects of our society and no longer have a wide-eyed wonderment about the society and the world they live in(6). This provides some explanation as to why traditional, teacher-centered discussion lessons are less than successful. In general, students are bored, feel powerless to change things in our society and are cynical of being participatory citizens, and in turn, active students(7).

The results of these forces on the school is demonstrated in many ways(8, 9). Lack of interest and skills in reading and writing; poor attendance and high cutting rates; high dropout rates; interruptive acting-out behavior; use of drugs or alcohol during school; and more than coincidentally, students' dislike of and non-attendance in science courses. Attempting to teach a particular subject matter such as science within the present context of today's high schools has become a frustrating and unsuccessful task, as demonstrated by both achievement and attitudinal statistics(10, 11). Science educators are also calling for reform, realizing that attempting to design curricula outside a complex framework that accommodates these social changes is fruitless(12). If there is to be an impact on students' attendance in and attentiveness to STS classes in schools, this matrix of changes must be addressed and STS classes can no longer be viewed separately, but must be looked at as only a component of the larger multi-dimensional program(13).

A program has operated for eleven years in an urban high school which not only has STS as an inherent component, but has drawn nationwide interest in its success with keeping at-risk students motivated, achieving and in attendance. The BONGO PROGRAM is housed at Middle College High School, a New York City public school, which itself has been named as one of the exemplary programs in the nation by the Carnegie Commission. The BONGO PROGRAM was designed to accommodate these underlying social changes that impact on our students. Most of the major school studies cited above describe, almost point by point, the multi-dimensional aspects of the BONGO PROGRAM when they prescribe the remedies needed to be enacted. Unlike many reform efforts, the BONGO PROGRAM attempts to accommodate the social changes by creating a positive alternative peer group and by having students actively engage in creating tangible, publicly presented projects during the academic school day. The projects grow out of an interdisciplinary study of traditional content based around personalized themes. As an outcome, the student's commitment to this all-involving academic program has increased attendance, lowered dropout rates, obliterated cutting in the program, increased student attendance to reading and writing, allowed new entrances into science and technology for phobic students and raised self concepts.

There are some features of the program that clearly differentiate it from traditional STS "infusion" methods. The subject area teachers team-teach in the same classroom at the same time. The terms are based around themes which contain science, social studies, English or art subject matter, but these subject areas are rarely taught separately. Most of the material covered, though it matches state approved mandates, is seen by the students as necessary to create the original PROJECT (e.g. play, book, video) later in the term. The methodology used in setting the tone of the program creates a supportive "family" type structure which creates an organic positive alternative peer group. The level of analytical thinking, cross-disciplinary interpretation, and support and respect for fellow students (and teachers) is always astounding to visitors from around the country.

Although there have been 27 separate curricular outlines, one for each term BONGO has existed, a brief overview of one 13 week term may elucidate some of its structure. The theme for the term was: the rights of the individual vs. the rights of society. We simultaneously began the study of genetic engineering and its social implications and the reading of the novel 1984. Each day, students role played family "decision making" situations relative to amniocentecis, etc. A filmstrip viewed led to a week long simulation of a court case involving a law mandating amniocentecis as a check for gross genetic mutations. Involvement in this led students to study Mendelian genetics, the bill of rights, judicial procedures, fetal development, etc. As we finished reading 1984, we began reading More's Utopia and student teams created presentations of their own Utopias.

Drosophila studies came into play as students wanted more proof of theory. Of course, all the background of cell theory, physiology, etc. was covered as needed. The students began Brave New World while the whole class began to write an original drama about an imaginary constitutional amendment which required abortion of all grossly mutated fetuses and its subsequent effect on our country. The play was produced, presented and impacted the public.

We realize that this approach is a major change for most schools, teachers and administrators. The risk-taking is too big for many people to take alone without support. For that reason we have sought and received some funding to replicate the program (The Echo Project) and are available to assist a limited number of sites who would consider implementing this type of program. If you are interested in a replication manual (The

Bongo Workbook @ $12.95) or in the replication program you can write to the authors at Middle College High School, 31-10 Thomson Ave., Long Island City, NY 11101 (718)482-5440.

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CURRICULUM DESIGN CONSIDERTIONS FOR TECHNOLOGY EDUCATION

James R. Gray

Technology has taken on vast proportions today, to the point that it has altered our definiton of life and living. It has modified in some respects our view of God, our value of self, and our relationships with our fellow man. The changes that have accompanied this cultural phenomenon have not been confined to the U.S. borders alone, but are worldwide, as recognized by such scholars as Drucker (1969, p. 31), and Burk (1980). This worldview is identified as a behavioral characteristic of technology that Ellul (1964, p. 116) has termed "universalism." At no other time in history has the human race been faced with a more seemingly insurmountable problem of dealing with ourselves and the technology we have created. However, if one were to view this situation as Vonk (1973, p. 517) does, this may well be "An Opportunity To Be Seized," which could result in closer human ties.

Many individuals scorn technology and view it as an evil. They advocate that it be stopped, or at least slowed down. Others see technology in a more positive light, requesting that technology be given less control for the benefit of all people. Neither suggestion has been completely reliable.

The scientists, technologists and others who occupy positions directly influenced by technology are aware of its consequences. However, the majority of the American population are ignorant or "illiterate" in this particular realm. Generally, the public equates the term "technology" with machines or with the manipulation of material objects that exist within their environment (Komoski, 1970, p. 2). Thus we are not prepared to understand the social/cultural implications that accompany the technological society we have created. In order to eliminate the lack of awareness Jacques Ellul (Mitcham and Mackey, 1972, p. 96), Paul DeVore (1972), p. 8), Daniel DeSimone (DeVore and Smith, 1970), p. 30), and others ardently advocate that the populous be educated about technology so that we will be able to understand and gain control over it for the glorification and not the destruction of humanity.

In order to achieve this state, educators must understand the relationships that exist betwen technology and education. But this is no easy task. The definitions alone that have been contrived to describe technology do little if nothing for the layman. And the number of definitions available seem to out-number the scholars who are actually engrossed in the study of technology.

The educational system has failed to address the need for a technologically literate populace. Even in a time when experts are calling for and emphasizing education, our public institutions have yet to heed the call. Instead, schools have relied upon the traditional curricula to meet the challenge of our technological society. They continue to allow outdated program structures to dominate the educational process. As a result the young continue to venture out into a world for which they are poorly prepared. And unless appropriate curriculum content is identified to convey the interrelatedness between the disciplines of science, the humanities and technology; delivery systems are analyzed for the purpose of selecting the ones conducive for such an endeavor; educators presently in the field are shown that such an undertaking is worth the time and effort that will be required for their understanding and participation, we will continue to fail.

Purpose

It is the purpose of this paper to set forth a conceptually oriented curriculum model. This work is oriented toward the mechanisms of four distinct, but mutually inclusive pedagogical areas of the educational process. These areas are: the knowledge base and the philosophical assumptions therein; the curriculum theory and design utilized; the instructional environment created and strategies employed; and the change process and implementation effort (see Figure 1).

In any total curriculum development effort one must not overlook the need to address each of these individual areas, and the implied relationships that exist between each area. If we view these areas collectively as a system, we can gain a more comprehensive understanding of the problems addressed in curriculum development. This model would guide our educational efforts toward a sound curriculum, one in which all aspects important to a technology education program are addressed.

Many educators have produced significant work in an effort to illustrate the relationship between the forementioned areas. Among them are McCrory (1974), Gray and Seder (1976), and DeVore (1980). Because of the specific scope of this paper we will be unable to fully cover each area and the inherent relationships. It would be of greater venefit to the reader to refer to the identified authors for a more thorough treatment of the total process as present in Figure 1. A summarizaiton of this system is offered herein with major emphasis placed upon the practical structuring of content derived from technology.

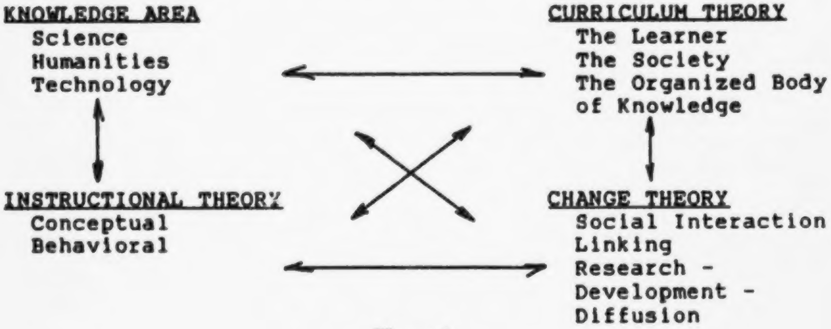
KNOWLEDGE AREA
Science
Humanities
Technology
CURRICULUM THEORY
The Learner
The Society
The Organized Body of Knowledge
INSTRUCTIONAL THEORY
Conceptual
Behavioral
CHANGE THEORY
Social Interaction
Linking
Research - Development - Diffusion

Figure 1

Pedagogical Areas of the Educational Process

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TECHNOLOGICAL LITERACY COMPONENT IN THE MIDDLE SCHOOL

Alain Hunter, Veola Jackson, Karen Griffin and Judith Scott-Hunter

The Technological Literacy Component in the Middle School is a five-year project undertaken at the Stuart-Hobson Middle School of the Capitol Hill Cluster Schools, District of Columbia Public Schools in collaboration with the Department of Industrial, Technological and Occupational Education, University of Maryland, College Park. The Component has five sub-components and three broad objectives. The objectives are: (a) to increase the awareness of the historical role of technology and human development within both the school and the community, (b) to facilitate participation in changing technologies, and (c) to promote an understanding of the social and environmental consequences of technology.

The five sub-components are the *Laboratory Sub-Component* (cooking and sewing; desk-top computing for word/data processing and drafting; audio/video production; and photography, drafting, electricity, and ceramics) that supports the other four sub-components, which are the *Exploratory, Competency Based Curriculum, Technological Literacy Curriculum, and Outreach.*

Hence, the Laboratory Sub-Component supports the -

- Competency Based Curriculum Sub-Component by providing it resources for the practicums that lead to the attainment of mastery of applied knowledge in the world of work, domestic management, and leisure

- Technological Literacy Sub-Component which will increase student awareness of technology in the areas of human development, decision making, values, changes in technology, and the social, environmental consequences of technology

- Outreach Sub-Component by providing a learning setting of current technologies of the work place for use by the immediate and greater community

The Roots

The success of the Capitol Hill Cluster Schools has been based, in part, on its different approaches to learning, its philosophy, its student and parent leadership, and its teacher administrator teams. In its urban setting the Cluster offers a creative approach to public primary and middle school education. Its programs, Pre-K through 8th Grade, offer arts and sciences, foreign language, technological literacy, special needs, community experiential activities, before and after school child care, and cooperative nursery and early childhood education.

The Renaissance

The geneses of this project were rooted in the community based efforts upon which the Cluster School's Educational plan was devised. As the plan crystallized, the planners were aware of the reports which cited low enrollments and lack of student interest in urban, traditional laboratory programs (Industrial Arts, Home Economics, and Business Education) and why equipment was underutilized and/or neglected (Solorzano, 1984). Consequently, the planning group developed the basic philosophy of the Technological Literacy Component. This philosophy was incorporated in the Educational Plan of the Cluster Schools and was approved by the District of Columbia's Board of Education in June 1986.

The Logic

The Community of the Capitol Hill Cluster Schools perceives a growing need to be - -

- sensitive and responsive to the "booms and "busts" or the "bull" and "bear" markets of the area's economy,

- aware of the technology revolution which appears to add a new dimension to the way that children learn, the way parents support their children, and the way that teachers must facilitate learning (Frankel, 1986), and

- aware of the technology migration into the metropolitan area.

Consequently, the Cluster Schools' community is guiding the Technological Literacy Component project toward learning experiences which stress independence, special projects, the interlinking of ideas, and the integration of skills and knowledge across curricula.

The Present

At this time more than 200 of the 357 middle school students are on the eve of engaging in the pilot phase of the Competency Based Curriculum Component. The focus of this pilot will be a science fiction theme with an emphasis in writing. The science fiction theme was chosen because of its popularity with early adolescent students. As Toffler (1974) wrote, "... one important tool for acquainting students with alternative futures should be the literature of science fiction. Almost by definition, this literature provides a body of works, extending back more than a century, which have taken as their theme the impact of change, particularly that derived from advances in science and technology " (p. 235).

The Future

As changes in the economy, technology, and the population's demography shape the education of this community, adjustments will be made in the Component. During the School Year 1987-1988, as the Competency Based Curriculum Sub-Component is assessed, efforts will be made to redesign and upgrade the laboratories, and teachers, peer teachers, and advisory committee members will have the opportunity to solidify their strategies and promote the utility of the technological literacy concept. This will include the test of a prototype computer network, which will facilitate the full implementation of the Technological Literacy Component Project.

The Capitol Hill Cluster Schools and the Department of Industrial, Technological, and

Occupational Education believe that learning should be facilitated in a manner that will bring all students to a level of competence which will better equip them for life.

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THE USE OF PROCESS ORIENTED TESTING IN THE DEVELOPMENT OF STS MODULES

Jack Robinson and Dianne Robinson

The equivocal results of summative, end of courses, evaluations for course improvement have been recognized for some time now (Cronbach, 1963), yet its use in setting standards and generating information useful for the practice of instruction continues to be advocated in many approaches to program evaluation (Worthen and Sanders, 1973). Seldom have individual teachers found results of such studies accessible and useful for their individual needs (Cross, 1987). Such outcomes oriented how approaches offer little direct help to the instructor whose interest is focused on how to facilitate the process of learning.

Testing and evaluation procedures that are an inherent part of the teaching learning process would better serve this purpose. This kind of formative evaluation is particularly relevant to the development of STS type modules which seek to enhance student skill in approaching science and science related issues. It is of particular interest to the Hampton program where the modeling of process oriented teaching behaviors by university level science instructors is an important component of the preservice teacher education program. Research on the process of learning to teach has shown that teachers teach in the manner in which they have been taught in their academic discipline.

Assessment which encourages working closely with students while they are in the process of learning should help instructors gain insight into student learning, and at the same time model behaviors likely to be adopted by the student when they become teachers. The formative, periodically during the course, evaluation procedure that has evolved in the Hampton Project specifically focused on teaching students how to pose and clarify questions, seek information, organize a plan of action, and prepare and evaluate reports. These skills were judged by science faculty to be important to the process of investigating science related issues and were thought to be lacking in the pre-science teacher. The specific activities and evaluation procedures for developing these skills were as follows:

Formative Activities and Criteria For Evaluating Modules

(Note each of the following may be done individually or as a group.)

1. Teaching Activity: Discussion and formulation of a STS type problem.
   Objective: The student will have an understanding of the problem posed' and have a clear focus for activity.
   Evaluation Activity: After the problem or issue has been posed have students formulate questions to guide their activity.
   Evaluative Criteria: Are students clear about the tasts?
   Are questions appropriately formulated?

Are questions just reformulation of what the instructor proposed or are novel questions also included?
Are students inquisitive and creative in their questioning?

2. Teaching Activity: Have student organize and prioritize activities for answering questions.
Objective: Students will be able to organize and systematically approach the collection of information relevant to a problem.
Evaluation Activity: As a group, have students outline a plan for data collection and list what they need to know or find out.
Evaluative Criteria: Is the plan feasible - is it reasonable given available resources?
Are areas in which adequate data may be difficult or impssible to obtain noted?
Are the resources to be consulted appropriate?
Is there an overdependence on text books?
Have resources other than those directly related to science been used to place the issue in social perspective?
Is the plan comprehensive?
Is the information to be gathered interrelated and appropriate to the problem?
Do the activities proposed show planfulness?

3. Teaching Activity: Have students prepare a position paper or report.
Objective: Students will be able orally or in writing to present a cohesive, pertinent response to a given problem area.
Evaluation Activity: Presentation of the position paper or report in writing, or orally.
Evaluative Criteria: Is the presentation logical?
Is the presentation comprehensive and does it address all the questions posed?
Is the presentation analytical and in sightful, or is it a superficial treatment of the problem?
Are positions taken and supported or not?
Has relevant information been sorted out, or is much irrelevant information presented?
Is there evidence of information having been weighed and evaluated?
Has the presentation been adequately communicated or are basic communication skills lacking?

Obviously, to make this a workable procedure some amount of effort will be required on the part of the instructor. However, as they proceed in its application much useful information may follow. That feedback may take many forms. For example, in examining work on students' ability to deal with questions about irradiation in the PLON project, Eijkelhof, (1985) noted instances where student interpretations were hampered by common misconceptions and predominant social concerns. A teacher normally would not be cognizant of the effects of such contradictions. Teachers are not in the habit of teaching about technologial problems from a multidisciplinary and social context. This could be enhanced by using results from formative evaluations. This format could be used to explore ideas, perspectives, values, the influence of social forces, feelings, and emotional reactions. Students lack of knowledge about sources of information is often unanticipated by teachers and directly focused on in these activities. This representes an initial approach to establishing a means by which faculty and students interact and modify one another's behavior, while coping with a problem that can be approached systematically.

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INTEGRATIVE INVENTION EDUCATION: TEACHING CHILDREN TO INVENT THEIR FUTURE

Wayne Perusek and B. Edward Shlesinger, Jr.

Introduction

1979 Item. A mother receives a severe neck injury in a rear end collision. Her eleven year old daughter devises a red light to be placed on the rear window with the caption "STAY BACK." The light is operated by a manual switch near the driver. She wins 1st place in her division in a state contest. A few years later it becomes an industry standard.

1979 Item. An eight-year-old talks to parents about grocery shopping. The typical shopping list, arrangement of food items, grocery cart and check out require handling each food item several times before leaving the market. The eight-year-old's idea: Place an on-the-cart scanner to read the Universal Product Codes. If an item is removed - it is subtracted. Containers are in the cart. Customer pushes the loaded grocery cart to a check out, pays the bill and departs. Each item is handled once.

1986 Item. Even with an umbrella you often get wet clothes in a windy rain. This young inventor's idea: A clear plastic shroud rolled up on the perimeter of the open umbrella. To operate you pull a cord inside the open umbrella and a clear plastic cylinder drops around you keeping rain off without impairing vision.

1987 Item. Cat owners often feed Morris with canned moist food. The spoon is messy - not easily cleaned. Eight-year-old's idea: Make the spoon out of compressed cat biscuit. Serve the moist food with it - then break up the spoon and add it too.

These children and their ideas are part of growing efforts and enthusiasm in various parts of the country to encourage inventive solutions to problems and to invention as a theme. It was my privilege to be one of the originators of the New Jersey Department of Education program on inventing begun statewide in 1978. We called it the MIT Contest - (Mini Invention - Innovation Team). It was part of the Technology for Children program.

Purpose and Brief Background

I'd like to share a little of those beginnings with you; then have Dr. Bill Shlesinger, inventor, patent attorney and author of "The Art of Successful Inventing" share some of his work and how he helped the New Jersey program and many others; and then suggest an approach to involve more people. We suggest to you that many more children -- all over the U.S. -- can not only be encouraged to invent and be rewarded for their ideas, but also to be taught: how to invent -- a much more powerful idea. And, that this invention work can infuse all areas of the school experience as well as all levels of education.

Inventing for children is now being more systematically introduced. Witness the

"Invention Convention" idea begun in 1984 and the "Invent America" program begun just last February, 1987 and the Society of American Inventors: "Young Inventors of America" in conjunction with the "Weekly Reader" and Project XL of the U.S. Patent Office to coordinate inventive thinking projects. Certainly, the idea is in the air. The emphasis is at the early grades - but the idea is not grade conscious. From the STS program: "Technological literacy means understanding the technological and scientific forces shaping our lives, and being able to act on this understanding for our personal welfare and the common good."

The key words: understanding/action/personal welfare and common good, all emerge in the inventing process and contribute to this literacy. More importantly, all these attributes, and more, accrue to children when given opportunities and methods to invent.

For example: as students deal with real problems growing from the technology, they are placed in a context. The problem or problems and individual initiative and creativity focus the action. The search for solutions and resolution lead often to enhancement of existing conditions, processes, hardware or methods or combinations. Both personal and public welfare grow from novel or inventive-innovative thinking. Student understanding of the problem, the context and the enhanced condition develops over time and with experience. As one result, technological literary expands and deepens enabling more comprehensive problem and opportunity engagement in a continuous growth and becoming process. Enhanced positive self-concept is reported over and over for participants in this process.

Positive self-worth and awareness statements and comments from young inventor-innovator participants include: keener awareness of problems, enhanced belief in self as inventor, forced opportunity to put ideas into model form, increased confidence as a problem seeker and solver, fun, humor and joy in the process and enhanced thinking skills applicable to broad conditions.

Some Benefits

1. Surely inventing is one of the finest and potentially powerful ways to integrate the technical and the academic for broad benefit and at all levels and encourage risk-taking.

2. The enhanced and new self-confidence from gaining recognition for having successfully dealt with a problem perhaps is near the top of benefits.

3. Problem searching skills and divergent thinking, as well as problem solving skills, overtime, help to develop a better sense of being a contributor to technology and help the "I can do it myself attitude."

4. Both girls and boys are encouraged to deal with the problems and often in a collaborative, team way.

5. Elementary- middle school and high school teachers, as sponsors, can infuse into regular work as much of this topic "Invention/Inventing/Innovation" as they chose. As a thematic approach, the topic crosses all disciplines. At minimum, teachers can encourage participation and assure guidelines and materials are offered to children.

6. Sponsorship for awards and recognition comes for the asking. Business and industry people are eager to support this effort. School and community are brought together as a result.

7. All areas of the curriculum, as well as other programs can easily infuse an inventing/invention component. Many schools have already established invention clubs and this idea, also, should be explored.

8. College and university infusion of invention education on a broader scale waits to be done. A great example is Woody Flower's Engineering 270 Course at MIT.

9. Some will argue that it is important to stimulate inventiveness without regard to awards -- that it is the effort that brings adventure and honor to faltering as well as successful work. Many more benefits accrue from such effort than we have cited here.

Technology for Children or (T4C) is the elementary component of a comprehensive plan for Vocational Education in New Jersey. Over the years it infused the technical with the regular academic K-6 and K-8 curriculum through a range of hands-on, learning centered materials and activities relating children's school experiences more directly to first-hand experience and the world-of-work.

As one of the state program staff, part of my role was to help establish graduate inservice courses for participants following our early Summer Institutes. In one course, the teachers made learning centers to reinforce basic skills and were based on at thematic approach.

One teacher, Dorothy Poling from Middletown Township, selected Invention as her learning center theme. She included models, articles about inventors and inventions, timelines and instructions on duplicating some ideas. Here was an idea to build upon -- why not suggest that children develop their own inventions out of daily problems? In the Fall of 1978, I had this opportunity and worked with two Middletown Township teachers Esther Pavelka and Cyril Millner and their 3rd grade children on invention. Many of the forty-three children created an original idea and modelled it. Out of that work came a statewide workshop for teachers and administrators at which the children presented their ideas.

At this time, a new office and program in state government came into existence -- the Office for Promoting Technical Innovation -- or OPTI for short. It's first Executive Director, Dr. Richard Stockel, addressed that first invention workshop along with Mr. John Prager, Manager, Technical Relations at the David Sarnoff Research Laboratories. Both men were inventors. The year 1979 was the 100th anniversary of Thomas A. Edison's Invention of the light bulb. Participants and children's enthusiasm at that workshop were so high, the suggestion came forward to get many more children involved.

My colleague, Laddie Gribick and I drew up some rough guidelines and gathered a group of program participants together to sound the idea. Together, we developed a plan. Two local supervisors, Pat Ratta from Wayne, NJ and Joan Dilger from Middletown Township, NJ chaired several committees of interested teachers and supervisors.

Support for contest awards in U.S. Savings Bonds, certificates, plaques and books on inventing and inventors came from such firms as:

GAF Corporation
Hoffman-LaRoche
State Farm Fire & Casualty Co.
American Cyanamid
Tenneco Chemicals
General Food Corp.
Women's American ORT
Exxon Research & Engineering Co.
BASF Wyandotte Corp.
Firemenich & Co.
North American Phillips
Bouland Industries, Inc.
Chemplast, Inc.
Atlantic Electric

The only reason more companys and corporations were not involved was because the organization of the contest was being established that first year. We initiated it in February and held the first State final judging in May. But we were underway.

Another event in 1980 was the publication of the U.S. Commerce Department's

Technical Advisory Board's May, 1980 "Recommendations on Learning Environments for Innovation." This board made such statements and recommendations as these:

> If we really wish to "encourage a new surge of technological innovation in U.S. Industry .... the pool of human resources for innovation must increase rather than diminish, and we must examine the institutions and environments in which such skills are encouraged and nourished." (p. 1)
>
> .... we must address the lack of curricular and technological literacy that is characteristic of the non-scientist. Despite the technological nature of our society, there is little concern that our managers and decision makers (and reporters and citizens) generally have only a token familiarity with the principles of science and technology around which our economics and life styles revolve. We need to change the image and training of the "educated" persons to include a reasonable familiarity with the technological culture of our times. (p. 26)
>
> An essential need of an education for technological innovation is to provide hands-on experience. (p. 27)
>
> Researchers who have looked at the differences between the left and right brained characteristics note that the logical and analytical left brain traits are easily identifiable, whereas the difference between the more visual, holistic, and creative right brain traits make it difficult to distinguish between true genius and mere eccentricity. Moreover, we are concerned that the present trends of back to the basics and dispense with the frills more and more eliminate the 'hands-on' experience which may be necessary to develop right brained skills which we believe are essential to innovative technologists and managers as well as creative artists. (p. 24)

And finally,

> Prizes and awards help to nurture early the rare talents that may go on to become the great innovators of their time .... one must recognize that not all awards are equally meritorious .... some may reward the ability to acquire book information without sparking an inquisitive or creative mind ...." (p. 22)

That publication was very timely and helped promote the contest already underway. U.S. News and World Report also headlined the need with "Innovation - has America Lost Its Edge." Much more has since been written.

The contest was open to individual children or teams: K-3, 4-6, 7-9 grades. Local winners went on to regional competition and 1st, 2nd, and 3rd place regional finalists went on to a state final.

It was at this time the work of Dr. B.E. Shlesinger, Jr. came to us in an article he had prepared for Educational Leadership. We set up an initial meeting with the contest committee. From this introduction came a series of workshops led by Dr. Shlesinger on the "Art of Successful Invention." In all, he worked in the next year with a cadre of about 150 principals, supervisors and teachers to help them teach inventing to other teachers and children. Teaching How to Invent now added that powerful idea and method to the contest. It is my great honor to have Dr. Shlesinger here to share with you some of his work.

The Art of Successful Inventing

"Everything has a beginning; with invention, beginnings are everything." Inventing helps us to solve everyday problems effectively and enables us to become more resourceful and more self-reliant. It is so strong a driving force that the story of civilization is the story of successive waves of invention that have transformed human affairs. Comprehending the development of invention enables us to understand the past and present and predict the future more reliably.

Today, fewer Americans apply for patents than in 1929. About 50 percent of all U.S. patents are granted to foreigners, compared with 1 percent in 1930. And in 1986, for the first time in the history of the U.S. patent system, which began in 1790, Hitachi, Ltd., a Japanese company, was granted more of our patents than any U.S. company. General Electric was second.

Invention is nothing more than correlating the information which we have at our fingertips to make something that has not been made before. Six-year-olds have millions of bits of information stored in their computer-like brains. Show them how to correlate information and they readily become inventors. Six-year-olds recognize the concepts of comb and triangle. When they are instructed to put these two concepts together, they invent new triangular combs. Eli Whitney put together the concepts comb and cylinder in 1793 and invented the cotton gin. This simple invention was a major force in the Industrial Revolution.

Because I am an inventor, most people think that I have a special set of keys that open doors closed to them. No so! There is no great mystery to what inventors do. For some 20 years, I have successfully taught students from university to kindergarten level -- and in prisons, hospitals and industry -- how to invent. The secret to inventing is using available keys in a systematic approach. With these keys, inventors open a series of doors, step-by-step, in five major categories. They identify a problem; research its background; collect data; apply imagination; and recognize limitations on potential solutions. In sum, the categories are:

IDENTIFICATION
FOUNDATION
DATA
IMAGINATION
LIMITATIONS

If you teach your students to use the keys in these categories systematically, they will astonish you with their creativity.

With Identification, we first seek a problem to solve. Necessity is indeed the mother of invention. There are three keys to identifying a problem: Stay alert for complaints, look for difficult or inconvenient situations, and recognize recurring breakdowns or injuries. Keep a list of problems for one day and you will turn up a number of areas in which you can work. A simple way to begin is to list all the advantages and disadvantages of the present invention or situation. Ask two questions: Can I improve the advantages? Can I correct the disadvantages?

Take, for example, the blackboard eraser. It quickly become dusty, getting chalk on clothes and hands. Once it is dusty, it does not erase properly. To clean it, you have to clap it against another eraser or a hard surface, raising a cloud of chalk dust. Here are several nuisances that can be eliminated by inventing an improved eraser.

To lay the Foundation for an improvement, we use two keys: the historical background of the invention, and classification of its characteristics. This research allows us to perceive where we have been and where we are now, and aids in showing us where we are heading. History makes us look at origins and development. Classification makes us look at such categories as size, weight and material, so that we are clear about what we have and can make a list of alternative possibilities.

When sand was a writing surface, for example, the writing instrument was a finger or a stick and the eraser was a hand, a foot or a twig brush. Later, slate became the surface and chalk the instrument. For years, erasers have been made of felt. Can they be made of other materials? What about using magnetic chalk and a steel writing surface? Can the eraser be a small air brush with a vacuum to pick up the magnetic chalk particles?

Collecting Data is a matter of asking key questions about the specific invention we are considering. These key questions are: What is it? Why does it exist? When is it used? Where is it used? How is it used? Who will be the use? How does this device work? Why does it work? How can the application of our five senses provide data? If we ask the right questions, solutions to the problem become apparent. The data allow us to analyze the advantages and disadvantages in the problem area.

There are many ways of applying Imagination to solve problems. The most frequent reason for the failure of inventors is an unwillingness or inability to change their preconceived notions about existing ideas. Invention occurs when a concept is altered in some manner. Inventing requires us to consider every possible aspect of a problem area and to overlook none.

Let's return to the chalk eraser. To stimulate imagination, use the following keys: Develop different images by considering synonyms, formulate different definitions of the problem; think of solutions that use combination, addition, rearrangement, deletion and substitution of elements; and apply physical forces such as heat, cold, light, and pressure to the problem.

Considering synonyms is a simple aid to developing new concepts. A thesaurus shows the synonyms for eraser to be abrader, blotter, brusher, canceller, cleaner, defacer, eliminator, eradicator, expunger, hoser, launderer, mopper, obliterator, polisher, purifier, remover, scavenger, scourer, scrubber, striker, swabber, sweeper, washer, and wiper. Now the words eradicator, launderer, scrubber, washer, scourer, hoser, mopper, swabber and cleaner imply the use of a liquid. Aha! We can alter the eraser by incorporating liquid into it, thus getting rid of the dust problem.

We can also combine two or more dissimilar inventions to produce a new one. Thus, a simple combination of a holder and a piece of chalk prevents the hands from picking up chalk dust. Or we can invent something new by substituting part of the device we want to improve with part of another one such as the replacement of chalk with a felt-tip pen filled with liquid chalk, which leaves no dust.

Present this simple problem to your students and they will think of all sorts of imaginative solutions to the problem of chalk dust. But there is always a final step in the process of invention.

Limitations are restrictions that limit the scope of the solution and conditions that are imposed by external factors. For people working on new inventions, these include laws, regulations, assembly, disassembly, transportation, packaging and the like. The limitations on solutions of classroom problems may also involve regulations, the physical environment, budgetary considerations, and so on. Making an invention practical and finding a solution that works are part of the challenge and part of the fun.

In the late 1800's Jules Verne wrote a novel about a trip to the moon. Everyone knew then that such a trip was technically impossible. But the book raised a realistic problem: How can we get to the moon? Further research on this one question led to many problems, some intricate, some not, each requiring a solution. It took nearly 100 years to solve them all, but we did it.

Jules Verne created further needs, new problems to be solved. We can also look at still-unsolved past or present problems and seek solutions to them. If we follow the simple steps set out here, we are bound to be successful. And we must teach this art of invention, of problem solving. There are problems all around us. Every student, teacher or worker has needs which can be solved to improve the conditions under which we work. We must accept the challenges of today's problems in order to advance tomorrow. If we do not, we shall soon be subservient to other nations that recognize that their potential to become leaders of the technical world need only be restricted by the efforts they make to solve problems.

Where To

Many more children all over the country would benefit by participating in invention contests and instruction. You have seen how one state began statewide. Others may begin locally or regionally. People in local districts, county offices, in state education departments and college and university campuses could begin more local-regional-state efforts. The mechanism, incentive, and instruction through an invention education newsletter for children and teachers would be one possibility. Such a newsletter could include invention ideas, what corporations do, tips on inventing, ideas from the field and suggestions for teaching inventing. Inventing provides the means for interdisciplinary study, interaction and understanding -- leading powerfully to Technological Literacy.

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EXEMPLARY MIDDLE AND JUNIOR HIGH SCIENCE PROGRAMS: STUDENT OUTCOMES IN KNOWLEDGE, ATTITUDES AND STS APPLICATIONS

Bonnie J. Brunkhorst

Introduction

Middle school science provides an opportunity for teaching science in the context of technology and society. The intermediate grades are the one point in our schools where most students are required to take science courses. Middle level educational philosophy encourages curriculum development with interdisciplinary connections. The pressures to meet perceived college admissions requirements that develop in high school are not yet in full force, and student attitudes toward using science knowledge can still be positively influenced. The early adolescent should have the opportunity to practice making responsible, informed citizen decisions and taking the resultant actions.

Traditional science education has focused on student learning in the knowledge domain. However, national assessments of student learning in science have shown a pattern of decline in knowledge achievement (National Assessment of Educational Progress, NAEP, 1978; Hueftle, Rakow, and Welch, 1983; Yager, 1981, 1986; Yager and Bonnstetter, 1984, 1985; Yager and Yager, 1984, 1985). These same studies have also shown that student attitudes toward science decline as students progress through their schooling.

The National Science Teachers Association (NSTA) Position Statement: Science Education for the 80's (NSTA, 1982), stated that science education could be improved by teaching science in a personal and societal context. A subsequent Search for Excellence in Science Education (SESE) included Middle/Junior High Science. Criteria for excellence were developed from the NSF funded Project Synthesis study. Ten programs were identified as national exemplars.

The exemplary middle/junior high programs provided learning environments where teachers modeled enthusiasm, curiosity and continuous learning. Students are encouraged to actively participate, question and share ideas in an activity based curriculum (Penick, 1985). The programs are designed to provide students with the opportunity to experience science in the context of their own world. Various science, technology, society (STS) threads run throughout their curricula.

Concerns related to student achievement in exemplary programs have arisen. Is science knowledge sacrificed for better student attitudes toward science? Do students learn more positive attitudes toward science than those in the general population? Do negative attitudes automatically accompany early adolescence? Are students learning to make connections between science and personal experiences? Are students willing to take responsible action related to what they learned in science?

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Design and Procedures

Thirteen key teachers in ten exemplary middle/junior high science programs were invited to participate in the study of student outcomes in their programs. Eleven teachers from eight programs administered three evaluation instruments assessing the domains of science education to one of their seventh or eighth grade classes: (1) The Iowa Tests of Basic Skills, Science Supplement, for the knowledge domain; (2) the Preferences and Understandings questionnaire for the affective domain; and (3) the Science and Society questionnaire for the applications/ connections domain (STS). the latter two instruments used NAEP items for assessment. Teachers were surveyed using a questionnaire from the Report of the 1977 National Survey of Science, Mathematics and Social Studied Education (Weiss, 1978) and one asking supplemental question (Bonnstetter, 1984). Data obtained were used to develop a profile of teacher characteristics and instructional practice.

The Iowa Tests of Basic Skills (ITBS), Science Supplement, Levels 13 and 14, provided student knowledge achievement data for comparison with national norms for grade equivalents, normal curve equivalents and percentile ranks. Student achievement in the attitude and applications (STS) domains were reported by percent responding positively to questionnaire item statements and compared with percent responses from national samples. Tests for significant differences between national samples and middle/junior high exemplary program data were made using the Z proportion statistic. Significance was identified at the .01 level of confidence, occasionally at the .05 level of confidence. Achievement in the attitude and applications domains were compared by gender for students in the exemplary programs. Figure 1 provides a representation of the research design.

Results

This study provides an overview of the status of student learning outcomes in exemplary middle/junior high science programs in this country in three important domains: Knowledge, Attitudes, and Applications (STS).

Student Knowledge

Each teacher administered the ITBS Science Supplement to each student in the class selected to participate in this study. Table 1 shows the results for each class by mean normal curve equivalent (NCE) for the class and by percentile rank (PR) derived from the mean NCE. Percentile rank represents that percentage of the distribution which falls below the given score. Therefore, using national norms, for test site 901, 94% of all students taking this test scored below the "average pupil" in the 901 class. NCE and PR scores were averaged to obtain the mean for the middle/junior high exemplary program students. For 280 students a mean NCE of 73.9 was obtained, a result considerably higher than the national norm of 50. The exemplar group NCE equates to the 87th percentile rank. Comparison with the national norm of 50 indicates an "extremely high" (H. D. Hoover, 1987) performance for the exemplar students in the knowledge domain. Using the pupil percentile rank from the mean NCE for a class, it is possible to say that for class 902 the average pupil in the class scored at the 91st percentile rank.
Therefore for the 280 students in the middle/junior high exemplary science programs, the average pupil scored at the 87th percentile rank. Likewise considering the "average pupil" in this group, 87% of the scores in the national distribution fall below the "average exemplar pupil's" score.

Student Attitudes Toward Science

This study has shown that in the learning environment exemplary middle/junior high teachers have created their students develop strong positive attitudes toward science

GROUP I: Exemplary Middle/Junior High Science Programs

Teachers

Student Outcomes

- Characteristics - Instructional Practice	- Levels of science knowledge (knowledge domain) - Attitudes toward science (affective domain) - Understanding of how science affects humankind (application domain)
Teacher Factors	Student Outcome Factors

GROUP II: Standard Middle/Junior High Science Programs (from national norms and assessments)

Teachers	Student Outcomes
- Characteristics - Instructional Practice	- Levels of science knowledge (knowledge domain) - Understanding of how science affects human affairs (applications domain) - Attitudes toward science (affective domain)
Teacher Factors	Student Outcome Factors

Figure 1 shows the factors evaluated in the study. Teacher and student factors for each group are described by data collected and analyzed for between group correlations. Comparisons of student outcomes between groups are made. Student outcomes by gender are also described and compared.

Figure 1. Teacher and Student Research Factor Clusters

(Tables 2, 3, 4 and 5) while demonstrating high levels of achievement in scientific knowledge. Knowledge is improved rather than sacrificed when students study science in a supportive and interesting environment. Correspondingly, the acquisition of scientific knowledge does not necessitate suffering and hardship. Fostering success in science courses does not require sacrificing all but the most academically inclined students.

It is also evident that the onset of adolescence does not automatically lead to negative attitudes toward science. There are science learning environments where a decline in attitudes is not experienced at the middle/junior high level. The students in the exemplary middle/junior high programs have demonstrated positive reactions toward science classes and their ability to function successfully in science.

Table 1. Middle/Junior High Programs Students Performance on the Iowa Tests of Basic Skills, Science Supplement, Levels 13 and 14 (N=280)

Class		Total			Male			Female	
	N=	NCE	PR	N=	NCE	PR	N=	NCE	PR
901	19	82.7	94	12	83.1	94	7	82.0	93
902	38	77.8	91	19	76.8	90	19	78.8	92
903	29	83.3	94	17	83.9	94	12	82.4	93
904	26	93.4	98	11	99.0	99	15	89.3	97
905	26	76.9	90	10	80.2	92	16	74.8	88
906	23	73.6	87	14	75.9	89	9	70.0	83
907	15	66.3	77	8	67.5	80	7	65.0	76
908	21	47.5	46	9	51.6	53	12	44.4	39
910	25	63.6	74	17	67.7	79	8	54.9	60
911	27	69.9	83	10	73.6	87	17	67.6	79
912	31	77.8	91	19	82.4	93	12	77.0	90
Exemplars	280	73.9	87	146	76.5	90	134	71.5	85
Nat'l Norms		50	50		50	50		50	50

Table 2. Middle/Junior High Student Perceptions of Their Feelings About Science Classes (Percent Responding YES).

Science Class Makes Me Feel:	A	B	C	D	Ex M/JH	Male Ex M/JH	Female Ex M/JH
Successful	42	36	40	59	52	56	48
Uncomfortable	36	20	22	9	8	6	10
Curious	36	30	24	71	69	71	66
Prepared to Make Decisions	40	32	31	63	47	56	37

A: (N=600), B: (N-600), C: (N=750),D: (N=900)
Ex M/JH: (N=280), Male Ex M/JH: (N=146),Female Ex M/JH: (N=134)

Table 3. Comparison of General Population Middle/Junior High Students with Exemplary Middle/Junior High Program Students with Regard to Their Perceptions of Their Feelings About Science Classes (Percent Responding YES).

Science Class Makes Me Feel:	NS	Ex M/JH	Z-Value	Significance
Successful	42	52	2.772	*
Uncomfortable	36	8	-8.692	*
Curious	36	69	9.128	*
Prepared to Make Decisions	40	47	1.955	**

NS: (N=600), Ex M/JH: (N=280)
* Significant at the 0.01 level.
** Significant at the 0.05 level.

Table 4. Comparison of General Population Middle/Junior High Students With Exemplary Middle/Junior High Program Students With Regard to Their Perceptions of the Value of Their Science Classes. (Percent Responding YES)

Things I Learn in Science Class:	NS	Ex M/JH	Z-Value	Significance
Useful in Daily Living	78	69	-2.873	*
Useful in Future	74	66	-2.444	**
Useful in Making Choices	52	38	-3.868	*
Useful in Future Living	74	80	1.936	

NS: (N=600), Ex M/JH (N=280)
*Significant at the 0.01 level.
**Significant at the 0.05 level.

Student Science Applications Abilities

The levels of social consciousness and responsibility demonstrated by our middle/junior high students in this study mirror those in adult society (Table 6, 7 and 8). Our national political climate and social values have apparently influenced our youngsters. Responsibility does not appear to be an experienced value in school science.

Table 7 shows that exemplary program m/jh students have learned that they can make decisions that can affect societal problems. However, Table 8 shows the

Table 5. Comparison of General Population Middle/Junior High Students With Exemplary Middle/Junior High Program Students With Regard to Their Perceptions of What it Would be Like to be a Scientist (Percentage Responding YES)

Being a Scientist Would:	NS	Ex M/JH	Z-Value	Significance
Be fun	49	44	1.385	
Be boring	52	29	6.598	*
Make me feel important	42	55	-3.588	*
Be lonely	59	12	14.613	*
N=	2500	280		

*Significant at the 0.01 level

surprisingly significant differences between the middle/junior high student sample and the general population sample in regard to willingness to address pervasive social problems related to technology personally. The m/jh students are much less willing to save electricity, clean up litter, separate trash, and/or ride in a small car.

Students in this study who have high achievement in knowledge and attitudes toward science did not learn to transfer their active use of science knowledge for decision making to personal action. They studied the use of data for drawing conclusions in school science, but they still do not "read labels before buying" or "look at all sides of a question before deciding", even though they are willing to "change their minds when ideas don't fit the facts" and do not "prefer being told an answer".

Conclusion

Exemplary middle/junior high science programs provide for active student participation in programs that involve various STS strands which relate science to the world of the students. Student attitudes toward science are positive, student science knowledge is far above national norms. It is apparent that making science interesting by relating it to their world does not sacrifice their learning the knowledge base of science. Their knowledge is apparently enhanced. It is also apparent that negative attitudes toward science do not necessarily accompany early adolescence.

Student achievement in the STS domain of applications is not as consistently positive as their results for knowledge and attitudes. It appears that the final step in the learning cycle is not being made: application, or personal action based on decision making experiences in the classroom. Students are not as successful with making the transfer from school experiences to their own actions in the real world.

NAEP data has shown in the past (Hueftle, Rakow, Welch, 1983) that students do not see the connections between school science and their lives. The assumption that they will make the apparently obvious transfers themselves is not valid. This study reinforces those findings. Active student involvement in school science with the development of strong positive attitudes and knowledge achievement does not automatically lead to transfer into the students personal lives. Academic experiences involving decision making do not equate with personal life decisions.

Table 6. Comparison of General Population Middle/Junior High Students With Exemplary Middle/Junior High Program Students With Regard to Doing Science Related Things (Percentage Responding Positively+)

How Often Do You:	NS	Ex M/JH	Z-Value	Significance
Try Your Ideas	40	46	1.678	
Believe What You Read About Science	64	64	0.000	
Check School Work for Accuracy	50	48	-0.552	
Read Labels Before Buying	62	38	-6.648	
Look at all Sides of a Question Before Deciding	78	65	-4.082	*
Believe Events Have Logical Explanations	60	66	1.705	
Prefer Being Told an Answer	69	35	-9.510	*++
Like to Figure Out How Thinks Work	69	56	-3.757	*
Change Your Mind When Ideas Don't Fit Facts	45	57	3.312	*++
Keep Working When Unexpected Problems Occur	52	52	0.000	
Feel Time Wasted When Idea Doesn't Work	58	30	-7.727	*++
Gather Variety of Information Before Deciding	46	42	-1.110	

+Positive = Always or Often NS (N=2500), Ex M/JH (N=280)
*Significant at the 0.01 level.
++Favorable results for Ex M/JH

Recommendations

This study has shown that in the national middle/junior high exemplary science programs the students' high achievement in knowledge and attitudes toward science does not automatically affect their personal lives. It appears that teachers need to stress the expectation for student action related to school experiences. The learning cycle needs to be completed in school. Students should be required to carry out some application of their school science decision making experiences. They should not stop with classroom decisions based on science knowledge. Teachers should build the application/action phase into their curricula. Students do not make the transfer to life without practice in their school experiences. Those who provide support for teachers should facilitate the exploration of strategies to address these areas of action.

A longitudinal study of student outcomes in these exemplary programs is being conducted in the Middle and Junior High Division, NSTA. Teachers are participating as research partners addressing the needs in their curricula based on their own student outcomes.

Table 7. Comparison of General Population Middle/Junior High Students With Exemplary Middle/Junior High Programs Students With Regard to Their Perceptions of Their Ability to Affect Science Related Social Problems (Percentage Respnding Positively)

I Can Do Something About:	NS	Ex M/JH	Z-Value	Significance
Pollution	67	78	3.328	*
Energy Waste	60	61	0.282	
Food Shortages	47	54	1.932	
Overpopulation	23	20	-0.998	
Diseases	3	38	2.050	**
Depletion of Natural Resources	36	44	1.168	**

NS: National sample information from Third Assessment of Science by the National Assessment of Educational Progress, 1978, (N=2500).
Ex M/JH: Middle/Junior High Exemplary Program Students, 1987, (N=280).
*Significant at the 0.01 level. **Significant at the 0.05 level.

Table 8. Comparison of General Population Middle/Junior High Students With Exemplary Middle/Junior High Program Students With Regard to Their Willingness to Solve World Problems (Percentage Responding Positively)

I Am Willing To, Even If Inconvenient:	NS	Ex M/JH	Z-Value	Significance
Use less electricity	87	79	-3.046	*
Use bikes or walk more often	87	82	-1.954	
Clean up litter	69	50	-5.428	
Separate trash	65	49	-4.504	*
Ride in small economy car	78	69	-2.873	*
Use less heat to save fuel	56	49	-1.937	
Use returnable bottles	88	85	-1.233	

NS (N=2500), Ex M/JH (N=280)
*Significant at the 0.01 level.

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DASH: A NEW APPROACH TO TECHNOLOGY EDUCATION

Francis M. Pottenger III

Starting in the Fall of 1986, the Curriculum Research and Development Group (CRDG) of the College of Education of the University of Hawaii, working with a consortium of seventeen universities, began development of a sequential and integrated science, health, and technology curriculum for the elementary school, kindergarten through grade 6. The project is called Developmental Approaches in Science and Health (DASH).

DASH attacks problems of the elementary school identified in the early eighties by a wide array of organizations such as the National Commission on Excellence, American Chemical Society, American Institute of Physics, National Science Teachers Association, National Science Board, and others that have a stake in science. It addresses such problems as 1) integration of basic concepts of science, health, and technology, 2) activity-centered delivery of content, 3) incorporation of recent findings in cognitive psychology and child development, 4) evaluation, and 5) localization of materials discussed here. In addition, through its consortium mechanism, DASH works at long-term usership by providing training and follow-up coaching for teachers using the program.

Integrational Organization

How to integrate technological and scientific content has long perplexed curriculum developers. DASH uses a *historical* approach to help create integration. General trends of the history of the health services, other technologies, and science are used to identify, integrate, and sequence conceptual content. DASH embraces the developmental hypothesis that the evolving conceptualization of children generally follows the developmental history of science and technology.

Technology is used in DASH to refer to the applied sciences, both service and production oriented, that focus on making practical use of knowledge. This includes health services, medicine, engineering, manufacturing, management, farming, hunting, government, schooling, etc. *Science* is used in DASH to refer to those fields of inquiry devoted to the making of new knowledge through systematic empirical investigation. This includes the physical, biological, and earth sciences. It also includes psychology, archeology, anthropology, and other social sciences.

Archeology, anthropology, and physiology show that the survival of our human species has depended on adequate water, food, air, sleep, exercise, protection, reproduction, way finding, and learning. Satisfaction of these basic needs dominated the lives of our ancestors and still dominates much of our daily activity. Historically, technology developed to enhance acquisition of these basics. In its early stages of development scientific study concentrated heavily on the impinging environment--natural history, astronomy, and meteorology and tended to look for generalizations that followed the practical lead of survival-centered technology.

In our modern society, optimum health and health service have become major social goals. Other technologies have expanded their intent, seeking to satisfy our most subtle psychological as well as basic survival needs. Science, though it has set its own agenda of research and explanation for five hundred years, is still inextricably tied to the tools and ideas of technology.

Following the historical model, for its K-3 content DASH draws upon the scientific, health, and other technological problems that characterized our historic grappling with natural reality up to the time of the Renaissance. The activities for grades 4-6 are modeled after problems that carry the student into the nineteenth century. At all levels, practical technological applications are tied in with the science explorations that seek explanation of why things work as they do.

Child's World Orientation

How does one use history when the devices of today's world are far more complex than those of earlier times? In DASH the answer is found in the fact that our basic survival needs still must be satisfied. Using these clues of history, DASH developers concluded that much of what the young student does in and out of school involves these needs and can be captured in instruction. DASH in its K-3 activities uses sanitation, body covering, safety in school and at home, finding one's way in the neighborhood, etc., as technological topics of the present. Observing, handling, and caring for animals and plants provide experience with the stuff of the farm, living models of the student's own biology, and a deepened sense of responsibility. Multi-year recording and correlating data on the moon, sun, and stars with months, seasons, and years; testing ways to deflect, prevent, and cushion the impact of collision; making pumps and ditches to water gardens--all deal with things and ideas that have deep historical roots and that students can see and use in their everyday living. Out of ancient technology, observation, and generalization grew the science of today. Through similar experience of parallel phenomena from their world, DASH students create anew the founding concepts of science.

Activity-Centered

Incorporation of the insights of cognitive psychology is undertaken through the structure of DASH content and its delivery system. Some examples will give a flavor for the approach. First, learning is a personal act of organizing the elements of experience into the knowledge and procedures that we remember. It is out of our memories that we abstract the substance to synthesize novel responses to new events. Second, the more intense and sustained a student's sensory and cognitive activity, the greater the probability of learning. Third, the more often concepts and skills are reinforced in later lessons in different contexts, the greater the probability of long-term recall of knowledge and skills and use in varied situations. Work in the field of multiple intelligence indicates that students have several kinds of learning capacities--kinesthetic, spatial, linguistic, and mathematical-logical among others. Involvement of all these intelligences can be identified in the operations of science and technology.

Joining these research findings with successful teaching practices, DASH is developing a sequence of seventy-five to eighty "hands on" activities per grade level that provide reinforcement by spiraling major concepts through the seven years of the program. Students work with problems drawn from their reality, invent solutions, and seek explanation through experimentation of their own design with equipment of their own making. The multiple intelligences of students are challenged through activities calling upon a range of skills, including graphic, verbal, written, lyrical, manipulative, reading, and quantitative. To develop the special talents of the individual, there is much small-group and extensional work.

Evaluation

It is recognized that elementary students undergo unpredictable spurts of intellectual development and sometimes linger for unexplainably long periods on some developmental plateau. Inability to perform a task today does not, however, indicate that students will be unable to perform that same task tomorrow. Therefore, evaluation of student progress in DASH is carefully tailored to be non-judgmental. Evaluation seeks to identify and record what evidences of concept and skill mastery exist at any particular time. This record acts as a tool of instruction to identify both for the teacher and student progress made and learning goals met. Philosophically, evaluation is seen as needing to be a psychological support to students rather than a negative control mechanism. Behind this is the overriding imperative that students discover that they can learn about and control much of the technology in their immediate lives and that as citizens it is their responsibility to reflect continuously on how that technology is affecting themselves and society.

Time

The concept of time is fundamental to our scientific-technological society. Yet child development studies tell us that because of its multiple uses in metaphor and suffixation, its several ways of measurement, and its intangible character, time as a concept is very difficult for children to grasp. For these reasons DASH has committed a full strand of activity to the study of time, beginning in kindergarten.

The concept of time is introduced through a scroll calendar. At the beginning of the day, the teacher and students pictorially record observations of the moon, weather, garden conditions, and temperature along with the day of the week, the date, and the names of special commemorations such as birthdays. At the end of each day, students are debriefed on their class activities and again pictorially record major learning events of the day. Important here is the use of the pictorial rather than the written representation because teaching is being done with students who do not yet read and have not fullly developed habits of coding their experience in words. However, these students have excellent capacity for recall when events are coded in a pictographic form.

Periodically the calendar is unrolled. Students march up and down its length, counting the number of days in a week, a weekend, long holidays, a moon cycle, a month. They note how long it takes things to grow, use terms such as *long time*, *short time*, *past*, *present*, and *future*. It is possible to use the calendar as a basis for discussion of sequence of events --the stages in the moon's cycle, stages of growth of plants in a garden--and cause and effect. Most important, students at a prereading level can see what they have learned. A serendipitous benefit results from debriefing children at the end of the school day about their accomplishments. The process prepares them to communicate intelligibly with parents about school, something most kindergarteners normally do poorly.

Time lines flow out of the calendar along with digital time, followed by analog time. This allows an early concentration on planning and a continuance of development of sequence and cause and effect in first and second grades.

A personal growth and development record is started in kindergarten and carried through the sixth grade, giving support to changes over half a lifetime and later evolution of rate studies.

Space

Conceptualization of distance, area, and three-dimensional space is also difficult for many students. DASH provides extensive experience in working with these dimensional entities through a mix of science and technology problems. These range from measuring the height of growing plants to the measuring of the distance between school and home; from determining the area of students' palms to the mapping of their classroom and field sites; from engineering of space utilization and building of minimal storage containers to measurement of the volume of the usable lumber in logs and estimation of the volume of the moon and sun.

Localization of Materials

DASH materials attack the problem of regional differences. Consortium members are responsible for development of localized materials that speak to the uniqueness of geographic regions. These include differences in ecology such as animal and plant populations, soils, climates; special concerns such as earthquake, tornado, or tsunami preparedness; local diseases such as Rocky Mountain spotted fever, anthrax, and tularemia; local agriculture, lumbering, wheat farming, and ranching; and local industry, mining, and use of canals and waterways. In addition, adjustments can be made where school boards make special demands on the science and health curriculum.

Project Status

In the summer of 1988 staff members of consortium universities will be trained in the use of kindergarten and first grade materials. Trial testing will proceed thorough the academic year 1988-89 with wider dissemination of revised materials in 1989-90. Meanwhile, development will progress on other grade level material in Hawaii. Two grade levels per year will be produced up through 1990, with the grade 6 materials being completed in 1991.

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CONSOLIDATING A FIELD: RPI'S DOCTORAL PROGRAM IN SCIENCE AND TECHNOLOGY STUDIES

Richard Worthington

Introduction

This paper simultaneously describes a new Ph.D. program in Science and Technology Studies at Rensselaer Polytechnic Institute and places the program in the context of STS as an area of scholarly inquiry and contemporary social concern. The fact that Rensselaer is devoting resources to the development of doctoral research and training in this area reflects an assessment throughout the university that the future of STS is bright. In addition to presenting the assessment of STS that underlies Rensselaer's commitment, topics covered in this essay include the goals of the Ph.D. program, its intellectual underpinnings and research orientations, the curriculum, and the type of student and career paths envisioned for the program. More than conveying information on a specific degree program, then, the purpose of this essay is to contribute to the ongoing discussion of the state of STS as an academic field and the programmatic strategies through which it can be further developed.*

STS and the Social Organization of Scholarship

The defining characteristic of scholarly inquiry is the detachment from social pressures which permits the development of knowledge for its own sake. But all knowledge is a product of culture, and expert observors of research and higher education have expended considerable effort in understanding the ties which exist between universities and other social institutions. Among these linkages are the funding of scholarship, the institutional means by which basic knowledge is applied to social problems, and the careers and other social roles taken up by college and university graduates.

New fields of inquiry are therefore shaped in part by the questions raised and needs expressed by various groups outside the scholarly community, and American institutions since the late nineteenth century have stood out from their European counterparts in their readiness to develop fields of study that have direct application. For example, the growth of geology and paleontology in the late nineteenth century was propelled by the federal government's extensive survey of geological resources and the development of a national transportation system; chemistry and chemical engineering were integral to the development of chemical products through the first half of the twentieth century in the first science-based industry; and political economy (later economics) had its origins in the desire of progressive elements from privileged classes to contain challenges from other social groups--including "robber barons" whose rapacity was thought to represent a threat to a stable capitalist order.

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*As we go to press, the program has been approved by Rensselaer and has cleared most of the stages of accreditation by the State of New York. Four students are currently enrolled.

Clearly, the rise of STS over the past few decades has in great measure been a response to the increasing centrality of science and technology to all aspects of modern life. When social concerns (whether the needs of business or concern for the oppressed) raise new research issues, scholarly institutions face a spate of organizational questions. Is the new issue ephemeral, or is it likely to be salient for a long enough period to warrant diverting attention from other issues? Can existing disciplines deal with the new questions, or must new combinations of expertise be assembled? Are there reasonable prospects of developing a secure funding base outside the university for investigating the issue? Because the answers to these questions are almost always tentative, the growth of new fields is typically marked by eclecticism of intellectual and organizational approaches, with many false starts. STS is no exception.

The eclecticism of STS has numerous manifestations:

1. The contention of intellectual perspectives--e.g., internalist vs. externalist history of technology, or the autonomy/controllability of technology in science policy studies;
2. Uneven development--the history and philosophy of science have been in existence almost as long as the modern research university, while political science and economics are just beginning to pay serious attention to science and technology;
3. Varying organizational formats--some programs are housed in engineering schools, others in humanities or social sciences areas; most programs are organized as research centers or interdepartmental units, a few are tenure-granting departments;
4. Varying applied/basic research and teaching/research mixes.
5. Widely divergent relationships to existing disciplines--some STS programs are an extension of a discipline, but a few take disciplines to be secondary to STS as a field.

One indicator of the maturity of a scholarly field is its ability to generate research questions from an established body of theory and methods. By this criterion, some areas of STS--perhaps contextualist history of technology or the "strong program" in social studies of science--have settled upon a core of relevant questions, even if the theoretical perspectives and methodological approaches used in studying them remain matters of debate. Other areas are less developed. As a colleague in political science put it recently, "the typical course in technology and public policy looks like it came from yesterday's *New York Times*". Through it all, however, STS programs have grown steadily in number.

One reason to be optimistic that this growth will yield more coherent research agendas in the future is the development and integration of scholarly societies which can give shape to research and other professional activities. The earliest of these in the United States were the History of Science Society (founded in 1924) and the Philosophy of Science Association (1935). Most of the societies in the field were created in the past decade and a half. These include the Society for Philosophy and Technology (mid-1970's), the Society for the Social Study of Science (1976), and the Science and Technology Studies Section of the American Political Science Association (1986). The

Society for the History of Technology was founded in 1958. The creation of the National Association for Science, Technology, Society (NASTS) in 1988 to serve as an umbrella organization for these and the many other groups comprising the STS community (including non-academic ones) is a particularly important milestone. Unlike the other societies, which were formed by professional academics representing a single discipline, NASTS views its role of promoting exchange among such groups as "anti-disciplinary" (NASTS News, February 1988, p. 3). The organization includes groups and individuals from primary and secondary education, the science policy community, public interest advocates, and a variety of other areas in addition to higher education. NASTS can thus help to integrate the intellectual content of STS across the separate disciplines while promoting intellectual, political, financial, and other linkages with social institutions outside academia. The intellectual specialization and organizational centralization characterizing STS over the past 15 years has numerous precedents in the rise of new disciplines, suggesting a maturation for the field that will be reflected in research agendas increasingly driven by theory rather than events.

The trajectory of developments in STS at Rensselaer has been typical of a new field. Rensselaer only began to experiment with adding social scientists and humanists with a science/technology focus to its faculty about twenty years ago. The first organizational embodiment of this policy came in 1975 with the formation of the Center for the Study of Human Dimensions of Science and Technology (HDC), which began offerring an undergraduate minor and an M.S. in Science, Technology and Values in 1977. Like most such centers, the HDC lived off soft money, with no staff of its own save for a single administrative assistant and a faculty member borrowed from the philosophy department. However, faculty and student interest in HDC was sufficient by the early 1980's that serious discussion arose about the benefits of replacing two service-oriented departments (Anthropology/Sociology and History/Political Science) and HDC with a single department in STS. This was done in 1982, at which time two philosophers, a psychologist, and a computer scientist joined STS along with all of the faculty from the above-mentioned departments. The department's first new degree program was a B.S. in STS. The addition of a Ph.D. will provide the department with a full complement of undergraduate and graduate degree programs, and symbolizes a commitment to STS as an enduring area of inquiry.

The accrediting body for doctoral programs in New York State recognizes three kinds of need for programs of advanced research and training: society's need for new knowledge, the need of educational institutions in the State to offer programs which are important to their basic mission, and the need for trained manpower. Of these, the primary need which the doctorate in STS seeks to fulfill is society's need for knowledge on the interactions of science and technology in society. At present, the utilization of knowledge on science, technology and society is largely left to persons whose familiarity with the topic has developed without systematic and expert guidance. In turn, the growth of knowledge in this field has often been a byproduct of research in institutions which differ from STS at RPI in mission and organizational structure.

Most graduate programs in STS are at the master's level. Of those offerring the doctorate, most focus on a particular issue, or view science and society from a particular discipline (e.g., Syracuse University's program in Technology and Information Policy in the

Maxwell School of Public Affairs, or the University of Pennsylvania's doctorate in the History and Sociology of Science). Only a few programs, such as Science and Technology Studies at Virginia Polytechnic Institute or perhaps History and Social Study of Science and Technology at the Massachusetts Institute of Technology, look at the broad range of technological phenomena from a multiplicity of disciplines. Rensselaer's doctorate is designed to make a distinctive contribution to the development and application of knowledge in STS because of the manner in which it draws upon and extends theory and method in the humanities and social sciences.

The doctorate in STS is also appropriate to Rensselaer's plans for the next quarter century. The Institute's Strategic Plan of 1987 lists three goals which are furthered by the Ph.D. in STS. These include enhancing RPI's position as a first rank technological university at the forefront of teaching and research, establishing leadership through the development of interdisciplinary programs, and providing a campus environment that nurtures critical inquiry. As to manpower training (which is addressed in a subsequent section), historical evidence shows that the programs which identify emerging research areas and train Ph.D.'s for new research and teaching positions at other colleges and universities have an important advantage in securing a position at the forefront of the field.

The basic goal of the Ph.D. program is therefore to broaden our society's concepts of science and technology. The purpose which underlies this goal is to enhance our society's ability to derive benefits from the development of science and technology. Rensselaer is an ideal place for this Ph.D. The Institute's technological orientation offers the research projects and expertise important in the social study of science and technology, and interdisciplinary research is central to its future plan.

Existing forms of research have only begun to penetrate the full implications of science and technology in our society. The social science and humanities disciplines provide an important resource for extending such inquiry, but their knowledge bases are typically perceived as essentially separate from one another, limiting their joint application in the absence of programs such as the one being developed at Rensselaer. It is this integrated utilization of a hitherto eclectic knowledge base that defines the aspirations of the RPI program.

Faculty and Research

The STS faculty at RPI have a history of collaborative work with their colleagues in science and engineering, including programs funded by the Lilly Foundation for cooperative professional development and the National Project on Engineering Ethics, a three-year, NSF-funded effort which involved scholars from across the United States and Canada. STS faculty have used the university as a subject of research in studies on the ethnography of scientific laboratories, the psychology of student computer use, and the politics of technical innovation. Currently, four STS faculty and two graduate students are working under an NSF grant on a project analyzing ethical and value conflicts which arise in applied industrial research facilities on university campuses, using two research centers at Rensselaer as cases.

The research of the faculty members in the Department of Science and Technology Studies falls into three inter-related areas.

I. Theoretical foundations of science and technology studies: Work in this area entails adapting, developing and applying empirical and normative theories from disciplines in the humanities and social sciences to help account for the underlying structures and processes of scientific and/or technical change. Many departmental faculty are constructing new theoretical perspectives that can help explain and interpret the distinctive dynamics of the scientific or technical professions as well as other key features of modern technological society, especially with respect to human values. To some extent, this theoretical work assimilates common theoretical perspectives and parallel empirical findings that are currently expressed in the separate languages and isolated spheres of the disciplines. Other work in this area uses this base of knowledge to move beyond the limitations of existing disciplinary perspectives on science and technology. Such research therefore explores how theories developed in this new, interdisciplinary context might in turn modify some fundamental theories in the existing disciplines, as has already happened, for example, in the influence of history of science upon conceptions of paradigm change now widely employed in social science.

Some research questions in this field include: 1. What are the roles of disciplinary vs. interdisciplinary perspectives in the work of prominent observers of science or technology in society (e.g., Robert Merton, Jacques Ellul, Lewis Mumford)? 2. Are conflicts in paradigms consistent across disciplines? 3. How does evolutionary theory account for competitive/cooperative models of human nature and social organization? 4. How is human posture-- the way we make places in the world with our bodies--related to the nature of inquiry in the social and natural sciences? 5. How are social values and power relations among different groups in society reflected in artifacts encountered in early textile mills and canals, or modern-day industrial machinery and consumer appliances?

II. Social organization of science and technology: Research in this area focuses on scientific or technological endeavors as forms of social activity. The patterns of formal and informal organization constituted by and encountered in such endeavors play an important role in shaping science and technology, especially with respect to serving human needs. Some research questions in this area include: 1. What role does scientific/technical education play in shaping key values and aspirations of scientists and engineers? 2. How do the interests and ideologies of professional scientists and engineers affect the assimilation of new technologies in various social contexts (the factory, the hospital, local communities)? What role do other constituencies (e.g., managers, workers, patients, consumers) play in shaping the development and application of such technologies? 3. How do factors such as social needs, advances in basic knowledge, and national politics interact in the development of new disciplines and changes of existing ones? 4. How are the ideas we experience as or label "pure" mental entities or "laws of thought" shaped by society and culture? 5. How do new technologies affect the culture of organizations?

III. Political and policy studies of science and technology: Research in this area focuses on how people define issues and set agendas for science or technology policy, how these perceptions and agendas change over time, and policy alternatives for dealing with current and future issues in science/technology.

Research questions in this area include: 1. What is the relationship of technological design to quality of social and political life? How have public policies affected the alternatives which predominate in specific cases? 2. What theories of freedom and justice can guide the polity as it grapples with the threat to privacy posed by new information technologies? 3. What approaches to decision-making work best in developing public policies on risky technologies? 4. What public policies have been most effective in promoting the international competitiveness of American industry while accommodating people displaced by industrial change?

Curriculum

The Ph.D. in STS requires 60 credit hours of study beyond the M.S. or M.A., including 30 credit hours for the dissertation. The curriculum is divided into four sub-fields: concepts and research methods; science studies; technology studies; and policy studies. Field examinations are required in three of these areas prior to advancement to candidacy.

The delineation of STS sub-fields around which the curriculum is organized provides a broad basis for the development of our graduates throughout their careers, including dissertation work in the research areas described above. The final definition of sub-fields in the curriculum came only after the committee charged with developing the Ph.D. expended considerable effort in a futile effort to force the emerging substance of STS into old disciplinary molds. Because six humanities and social disciplines are represented within the department, and many faculty draw on disciplines from outside the department (e.g., political economy, architecture, computer science), this was a virtually impossible task. The Gordian knot was cut when committee members recognized that they had little interest in forming the program from existing disciplines in the first place, and that faculty responses to a survey of ideas for Ph.D. level courses fell naturally into the four sub-fields which now define the curriculum.

The existing and proposed courses to be offered in each of these sub-fields are listed in Table 1. The concepts and methods sub-field is self-contained as a component of the curriculum because it provides a base for all work in STS. Courses in the other sub-fields overlap with one another, but in a less consistent fashion. Thus, a course such as Philosophy of Mathematics deals with science as distinct from technology, while The Sciences in Modern America examines science in part by revealing how the institutional structure of technological growth helps to shape scientific research agendas. Within these sub-fields, then, there are overlaps with other subfields, while some courses (designated as "bridge" courses in Table 1) actually take these interrelationships as their principal focus. Students who specialize in science studies or technology studies will therefore be required to take courses designed to show how these areas are interdependent. Also, all students specializing in policy studies are required to take a field exam in either science or technology studies, thereby providing the unique foundation for policy analysis, formation and implementation available in this program.

Student Recruitment and Placement

The primary consideration in evaluating applicants for admission to the program is evidence of their ability to conduct original research in STS. The admissions issue highlights a fundamental difference between the goals of the M.S. and the Ph.D. in STS. In the former case, admissions criteria have a stronger individual orientation. Some students come to the program with an engineering or science background, and use the program as a means of extending an interest in the liberal arts that was piqued during undergraduate years. More often than not,

Table 1
Course Structure of Doctoral Program in STS

Concepts and Research Methods in STS

Concepts in STS I & II*
Advanced Theory Seminar+
Policy Seminar+
Research Methods for STS*
Values & Policy*
Research Design (qualitative)+
Research Analysis) quantitative)+
Advanced Topics in Research Methods:
  Historical Methods, Information
  Processing, Bibliometrics
(1 credit)

Policy Studies

Values & Policy*
Advanced Topics in Values & Policy:
  Computer Ethics, Health Policy,
  Ocean Resources, Global Corporations,
  Energy Planning, etc.
Industrial Policy
Politics of Technological Design
Public Policy & Energy Development
World Energy Politics
Risky Technologies

Science Studies

Philosophy of Mathematics
Scientific Revolutions
Theories of Human Nature
Metaphysics
Social Relations of Science
Early Science & Western Civilization
History of Modern Science
The Sciences in Modern America
Fraud and Misconduct in Science
Topics in Philosophy of Science
Ethnography of Science
Social Analysis of Science
Metaphysical Foundations of Modern
  Science & Culture

Technology Studies

Environmental Philosophy
Business Ethics
Economics of Technological Change
Structure of American Industry
Industrial Revolutions
Technology & Work Life
Human Dimensions of Biomedical Technologies
Technological Innovation
Arms Control & Disarmament
History of American Technology
Archaeology of Industrial America
Social Analysis of Technology
Justice in Technological Society

Bridge Courses

Seminar on Interrelations among Science, Technology, & Philosophy I & II, Cross-Cultural Perspectives on Science & Technology, Historical Studies of Science & Technology: Modern Scientific Institutions, Engineering in America, Material History, etc., Politics of Science & Technology. Careers of Technical Professionals.

+ Required for the Ph.D.
* Required for the M.S.
** Students must take at least two "bridge" courses beyond the M.S. which may be applied toward field requirements in Science Studies or Technology Studies.

such students report an intention to move away from a career path within engineering and science and into one which still "uses my technical background." A smaller number of scientists and engineers at the master's level intend to continue on technical career paths and expect that, in addition to personal intellectual growth, the M.S. in STS will provide opportunities to enter management positions later in their careers. Students with undergraduate degrees in the humanities and social sciences, on the other hand, use the M.S. in STS as a means of specializing. Many go on to work in policy-oriented positions where the emphasis in graduate school on science and technology is an asset in the eyes of employers. The admissions criteria for M.S. students have therefore come to place emphasis on the likely paths available to graduates in relation to individual goals.

By contrast, the mission of the Ph.D. is to move knowledge forward in a new field. The implication for admissions policy is that students must enter with equivalent educational preparation in the field: the diversity of backgrounds that is an asset in the M.S. program, which is a broadening experience for many students, or a sustained encounter with scientists and engineers for others, would be problematic for the Ph.D. because there would not be a sufficiently common knowledge base for accomplishing the mission of defining and developing a field. As a practical matter, a degree equivalent to Rensselaer's M.S. in STS will be an entry requirement. It is expected that most graduates of the program will continue in academic or other research-oriented careers. Given the condition of the humanities and social sciences in higher education today, the placement issue was a challenge to the department. Early discussions in STS centered on the prospect that Ph.D. graduates could obtain employment in government and industry as planners, researchers, and consultants. Interestingly, faculty outside the department and senior Institute administrators encouraged the department to design the program to train academics. This helpful nudge moved the STS faculty out of a conservative posture, and with good reason. For one thing, basic research is a strength of STS at RPI which should not be ignored in the design of its programs. Furthermore, the prospects of providing manpower for an emerging academic field is attractive, even if risky. Finally, experience with the M.S. program indicates that graduates will encounter little difficulty finding applied positions should circumstances or personal goals so dictate, notwithstanding the lack of an applied emphasis in the curriculum.

STS is both too small and too dynamic as a field to be amenable to a precise market analysis. However, Table 2 gives a general impression of the scope of academic opportunities in the field. The data in the table were compiled by reviewing catalogs for approximately 600 major colleges and universities, and cross-checking the results against the mailing list of the Student Pugwash organization, the History of Science Society 1986 Guide to the History of Science, and the AAAS Survey of Graduate Study in Science, Engineering and Public Policy. This search turned up 151 programs at 71 colleges and universities.

The programs in Table 2 were selected for inclusion only if the university's own literature referred to a research or teaching program with a separate title. The potential academic job market for graduates of Rensselaer's doctorate in STS is considerably larger than the table would suggest because the sample is limited, and much of the ongoing work in the field is taking place in organizational contexts which are not publicized as being concerned with science and technology studies. Some examples of such work include (1) individual courses or concentrations of courses offered in traditional departments (e.g., sociology of science in a sociology department); (2) sub-disciplinary specialities at the graduate level which are not advertised as separate programs or concentrations (e.g., the history of science specialization at the University of California, Berkeley in the Department of History); (3) institutions which have advertised for a faculty member to teach new courses in STS, but which as yet have no program (e.g., Lewis and Clark College); (4) institutions which have received foundation funding to teach STS courses, but that do not yet offer them (e.g., Reed College, which has received a Sloan Foundation grant to develop history of technology sections within its humanities courses); (5) technologically-oriented institutions which incorporate STS into an

TABLE 2
STS Programs in the U.S.

Name of College or University	(see key)				
	1	2	3	4	5
The American University			x		x
Auburn University			x	x	
Babson College	x	x			
Boston University	x	x	x		x
Brown University	x		x	x	
Calif. State Coll., Dominguez Hills	x	x			
Calif. State Coll., Stanislaus	x				
Univ. of California-Berkeley					x
Univ. of California-Los Angeles			x	x	
Univ. of California-San Diego	x				
Univ. of California-Santa Barbara			x	x	
Univ. of California-San Francisco			x	x	
Carnegie-Mellon University			x	x	
Case Western Reserve University	x	x	x	x	
University of Chicago			x	x	
University of Colorado	x				
Cornell University	x				x
CUNY-City College				x	
University of Delaware			x	x	x
University of Denver			x	x	
Duke University			x	x	
Eastern Michigan University			x		
Florida State University			x	x	
University of Florida			x	x	
George Washington University			x	x	
Georgia Institute of Technology			x	x	
Grinnell College	x				
Harvard University			x	x	x
Illinois Institute of Technology	x	x			x
University of Illinois-Urbana			x	x	
Indiana University			x	x	x
Iowa State University	x		x	x	
Johns Hopkins University			x	x	
University of Kansas			x	x	
University of Kentucky-Lexington			x	x	
Lehigh University	x				
University of Maryland			x	x	
Massachusetts Inst. of Tech.	x	x	x	x	x
Michigan State University	x	x	x	x	
Michigan Tech University		x	x		
University of Michigan				x	
University of Minnesota			x	x	x
Montana State University			x		
New Jersey Institute of Technology		x			x
University of North Carolina			x		
University of Notre Dame			x		
University of Oklahoma			x	x	
Oregon State University		x	x	x	
Penn State University	x				
University of Pennsylvania			x	x	
University of Pittsburgh			x	x	
Polytechnic Institute of NY			x		x

TABLE 2 (cont.)

Name of College or University	1	2	3	4	5
Princeton University		x	x	x	
Rensselaer Polytechnic Institute	x	x	x		x
Rutgers-New Brunswick			x	x	
St. Louis University	x				
San Francisco State University	x	x	x		
San Jose State University	x		x		
Stanford University	x	x	x	x	x
SUNY at Stony Brook	x		x	x	
Syracuse University				x	
University of Texas			x		
Vanderbilt University	x	x	x	x	
Vassar College			x		
Virginia Polytechnic Inst. and State University			x	x	x
Washington University			x	x	
University of Washington			x	x	x
Wellesley College					x
Wesleyan University		x			
West Virginia University					x
University of Wisconsin			x	x	
Total	23	16	51	43	18

Key:

1-Undergraduate Minor or Concentration
2-Bachelor's Degree
3-Master's Degree
4-Doctoral Degree
5-Research Center

undergraduate program for non-majors in the humanities and social sciences, but offer no degrees nor any special label for STS activities (the most salient example is Worcester Polytechnic Institute, which recently hosted the annual meeting of the Society for the Social Study of Science); (6) research centers and degree programs which intersect with STS but do not have it as a primary focus (e.g., the Center for Strategic and International Studies at Georgetown University).

Conclusion

To be sure, the design of the Ph.D. in STS at Rensselaer entails substantial risk that the field may fail to advance beyond the intermediate level of coherence seen today, and might even deteriorate. Alternatively, the field might do well, but the challenging task of playing a leading role in its development could turn out to exceed the resources available at Rensselaer. The collective judgement of the students, faculty, and administration at RPI is that the possible rewards are worth the risks. STS continues to grow and consolidate, and the time period over which this has occurred has been long enough for the initial growth curve to flatten out, and for good-but-impractical programs to fail. The fact that modest growth in STS continues, and that our society will be increasingly affected by developments in science and technology, provide sound historical grounds for the expectation that STS will will evolve into a stable area of scholarly inquiry.

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STS PROGRAMS FOR UNDERGRADUATE SCIENCE STUDENTS: AN ESSENTIAL TENSION BETWEEN SCIENCE AND SOCIAL STUDIES OF SCIENCE

José van Eijndhoven

Introduction

The purpose of STS programs for science students at universities should be to enhance their understanding of science and technology in society in such a way that they (as scientists) will be able to deal with choices in science and technology taking the social context into account.

To fulfill this purpose, literacy in social studies of science is less important than acquaintance with situations in which science and technology are used in society, and how these situations are handled and can be handled by society and themselves.

In the Netherlands, STS programs were established starting around 1970, first of all in rthe curricula for chemistry students. The start of these programs resulted from a demand by students; science faculty was mainly involved in running the programs. The content as well as the volume of the programs have evolved differently at different universities. Some programs consist mainly of optionals whereas others belong to the compulsory part of the courses. At Utrecht University the program for chemistry students is the largest compulsory program in STS existing in the Netherlands and the content is closely related to the chemistry curriculum.

The program developed this way because of a continuous tension between the wishes of STS staff, the students and other faculty. I will argue that from the perspective of giving science majors a broader perspective of science in society, and to enable them to act upon it, this is an optimal situation; whereas on the other hand, the situation may be inherently unstable.

To argue this I will first discuss the contents of the program, how it developed, and finally, the tensions influencing its shape. I think that the arguments raised do not apply only in the Netherlands.

The Utrecht University STS Program

The STS courses at Utrecht University have a relatively close relationship to the major topic the student chooses. Different courses are run for physics, chemistry and biology students. The topics discussed in the courses make use of and enhance their scientific knowledge. A short discussion of the chemistry STS program will clarify this.

The freshman course contains two parts, one 40 working hours (the 'module'), and another 60 hours (the project). For the module the student can choose between two topics: (aspects of) biotechnology and (the use of different types of) batteries. In the module work the students are asked to advise some quasi-existing body, taking the social aspects into account. In the project the students apply the skills learned doing the module on a self-chosen topic (within certain boundaries).

In the second or third year, another course must be taken, which consists of two parts: a lecture series (130 student hours) and another project. The lecture series starts introducing industrial chemistry using examples of large scale processes. This information is then used in a number of lectures about the economics of the chemical industry including innovation. Afterwards, the side-effects of chemical production are discussed, like the waste problem and environmental effects.

In the second part of the lecture series, these side effects are taken as a starting point to treat methods to assess and lessen the side effects. Among the methods discussed are toxicological methods, environmental impact assessment, technology assessment and risk analysis.

In the last part of the lecture series, some philosophical and sociological notions are introduced starting from a discussion of the role of experts in a practical situation that is shown on video.

In the project, the students are allowed to choose their own topic, but it is suggested that they take topics closely related to those treated in the lecture series: innovation and assessment of science studies type of topics. The former is by far the most popular, but the latter will sometimes be chosen in relation to some interesting new scientific development, like superconductors. The students are strongly encouraged to use interviews to gather their information and they are trained in interviewing. As a result they contact (mostly) scientists in all kinds of occupations. No longer freshmen, they are normally enthusiastically received by people from the chemical industry and elsewhere, because they are likely to become possible recruits or colleagues in the future. The students get an experience of chemistry in the real world outside the laboratory, without committing themselves directly. The students are asked to discuss and write down their experience in the project, thereby enabling reflection on the content of the project and the events that happened.

Additionally, options can be chosen that vary from a small lecture series (24 lectures) about 'Chemistry in Cooperation' (topics are environmental pollution, biotechnology and new materials) to a research year (centered around the optimalization of assessment studies, especially risk assessments) and a graduate course on technology assessment organized together with other Dutch Universities (Free University and Twente).

Tension

The history of the program I described was characterized by fierce intervention of other faculty and students. The freedom of choice in the project topics were heavily contested by students critical of the small amount of free topics in their curriculum. An effort of the STS staff to introduce a course on the sociology of science was boycotted by students that did not think such a topic socially relevant. Staff outside STS with an industrial past emphasized the importance of industrial chemistry, etc. By utilizing the opportunities opened up by the active interest of a small group of people and of the fact this group was very divided among themselves, it was possible to develop a relatively large program, of which especially the middle part, appears very attractive to chemistry students. But apart from the historical circumstances that influenced the specific shape of the program described, there are permanent tensions influencing the direction of STS programs.

The Perspectives of the STS Staff

When STS was started as a focal point at Dutch Universities, the programs were started by enthusiastic scholars and also very enthusiastic students. The programs were not very professionally organized in the beginning because in many cases no specialized staff was attracted, nor were the aspects to be taught very clearly defined. After a number of years of STS education, staff has become available either by attracting social science teachers or by reorientation of staff in science departments. Recently, STS staff may be recruited from one's own 'STS-breed.' The situation now is that at most universities STS staff consists of professionals that have become scholars of their own, quite a number of them in science studies but others more oriented towards impact assessment studies and the like.

At Dutch universities recently, much attention was given to generating high quality research, and staff recruitment and evaluations for tenure have been heavily emphasizing research achievements to the detriment of teaching achievement. As a result of these pressures, STS staff generally has become qualified in fields that more often than not are social science oriented, and in which natural science may play a minor role. In some other cases the staff has oriented its research towards applied science, having no clear social science component in their research.

As a result of these developments, the first generation of STS teachers still feels strained by having to prove themselves in areas in which they received little or no formal education, whereas the coming generation runs the risk of being oriented toward one aspect (either social studies of science or applied science) without being at home with the other.

The pressure on STS staff to become (or stay) qualified in a certain research area tends to take them off an orientation directed towards the primary aims of STS education. To further these aims they should be assisting students in learning to deal with choices in science and technology taking the social context into account. As I will argue further, courses in social studies of science may not do for that aim.

The Orientation of the Students

Most science students become science students in the first place because they are interested in science rather than the study of social aspects, and in quite a number of cases science students are not the most socially skillful persons.

When these persons are confronted with the social aspects of science, especially in their freshman year, they tend to be only marginally interested as soon as they do not see the immediate relevance of the information provided for their own situation, now or in the foreseeable future.

As a result, a large proportion of the students will tend to leave optional courses in topics related to STS aside, especially when they are assessed as having no direct relation to other courses. Compulsory courses may meet the fate of being consumed with little appetite. Worthwhile courses, of course, will still attract a relatively small group of students, even if only because they like to do something 'completely different.'

This orientation of science students means that for a course in STS to be effective, the topics offered should have a clear relation to the main program the students attend. The courses should relate to their professional orientation and should (in the view of the students) contribute to their future professional performance. Quite a number of students will not be of the opinion that social studies of science do so.

Is There a Way Out of the Tension?

From the title of my paper you can learn that I think the tension between the orientation of STS staff and students is essential. STS staff should try to enhance their understanding of the social aspects relating to the way science and technology operate in our societies. Science students cannot be expected to become social scientists, even halfway. Therefore, diverging pressure will keep influencing STS courses to keep them in the right direction.

The problem, however, is that such a situation is inherently unstable. If faculty is not continuously feeling the tension and acting on it, STS programs sooner or later will end up being options as any other. If courses in STS are compulsory, they will be taken with distaste by a large number of students, and will be of little avail to the objective of STS. This is the most probable scenario to come out of the situation sketched, and all faculty that finds itself in a relatively stable research position is not immune to it.

However, there may be one way out of the dilemma. And as is the case in many a dilemma, it is for us to take the challenge. In this case, the challenge may be to institutionalize a new way of doing technological research. That is to do technological research with the additional aim of providing handles for society in dealing with technology. If adding assessment aspects to research gets an impetus and will become accepted as scientific, then STS programs may in the long run still disappear, but in that case by taking over the whole curriculum.

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PHOENIX: AN INTEGRATED FRESHMAN PROGRAM

Sarah F. Perkins and Gary R. Gentry

Phoenix is one attempt to integrate STS courses into our college curriculum specifically at the freshman level. Phoenix is an integrated freshman program of interdisciplinary courses which focus on the development of critical thinking, skills in how to become better learners, and mastery of the subject. The program involves a commitment by the students to three academic courses and one physical education course over fall and winter quarters. The more unusual dimension of the program is that one of the four courses is in physical education.

Sixteen students are selected through an application and interview process which involves approximately 50 to 60 applicants. The students study together for two quarters taking two Phoenix courses each quarter. This schedule allows the students space in their schedule to enroll in other courses since a normal student load is three academic courses per quarter. All four of the courses fulfill all-college requirements.

Fall Quarter	Winter Quarter
Hist. 205 Modern U.S. History	Econ. 201 Macroeconomics
PE 39 Team Dynamics	Bio. 110 Environmental Sci.

The mix of courses may seem unusual, but we are finding that they work quite well together. We believe that the first quarter of the program should help the students learn to communicate and work well with one another. In the history course students work to refine group discussion skills and work on writing thesis research papers through an analysis of the main issues and problems associated with world history. The P.E. course, Team Dynamics, is designed to develop the students' qualities of leadership, trust, loyalty, and cooperation through understanding team experience. The academic faculty also participated in the Team Dynamics course. With this literal blending of physical and academic aspects of their college experience, the students had familiarity with one another which lead to more fluidity and sharing of thoughts and language in the classroom study. We found students referring to experiences they were having in the P.E. class in the history course as well as in the classes winter quarter.

The two academic courses taught in the winter are interdisciplinary and integrated. The faculty team teach and plan jointly the topical questions to be studied, as well as share materials, assignments, and guest speakers. The courses are actually united into one "super" course which explores the interplay of environmental and macroeconomic issues. This integration is demanding, but the skills and attitude developed in the fall quarter serve as a solid foundation for the winter courses. We have organized the course topics and thesis research papers and formal discussions around six questions:

1. Can environmental and economic universals be integrated to achieve a sustainable world?

2. How can the world feed itself on a sustained basis? (Focus on economic and environmental concepts to address the question.)

3. How can markets help sustain natural resources and biodiversity in the world?

4. Is the present acquisition and use of the world's primary energy sources sustainable?

5. Must the world be rid of pollution in order to be sustainable? Explain.

6. How should economi [illegible] environmental universals be integrated and applied to achieve a sustainable world?

The texts we use for both the environmental science and the macroeconomics present foundational information in the disciplines. We also have texts and readings that are issue oriented and lend themselves to examining the environmental and economic aspects of the issues. We have had to be persistent in locating appropriate books for the macroeconomics dimension since the standard college texts do not readily fit an interdisciplinary approach to the subject. The students supplement the readings through their own research of the issues.

In a program like Phoenix which addresses disciplines with an interdisciplinary perspective and addresses the student skill building needs of the freshmen (i.e. developing discussion, writing, and research skills) it is imperative that the faculty involved want to be in the program. The faculty must make time to meet regularly to coordinate the activities and demands on the students. Where team teaching is involved, there is no doubt that the time demand on the faculty is much greater than in a regular setting, but we believe that the outcome of such an approach for the students is very positive, stimulating, and contributes to their developing sense of integration. The faculty must be in agreement on the purpose of the program, their goals and objectives. Compatibility in teaching styles is important.

Programs such as Phoenix are demanding. This one was faculty initiated. We like what we are doing. Students seem to get involved -- some even discover that they like science! The possibilities for developing programs to get new students involved in science, technology, and society are exciting.

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ONE APPROACH TO DEVELOPING A SCIENTIFIC AND TECHNOLOGICAL LITERACY PROGRAM FOR LIBERAL ARTS AND BUISNESS STUDENTS

Victor A. Stanionis

Introduction

Scientific and Technological Literacy (STL) is a multi-faceted effort at Iona College, one which has included: the building of a major facility, curriculum development, an ongoing lecture series and the dissemination of curriculum ideas through the Science and Technology (S&T) Fellows program. The project has a ten year history, during which time a major curriculum incorporating the teaching of problem solving into the scientific and technological literacy courses has been initiated.

History

In the late 1970's, the Iona science faculty came to the realization that the science courses offered at the time were not preparing liberal arts and business students sufficiently to confront every-day problems having scientific and technological content. The chairs of the Biology, Chemistry and Physics Departments were unable to find an existing program that would meet Iona's goals and needs, and so, an active curriculum effort in the area of scientific and technological literacy began during the 1979-1980 academic year. Simultaneously, the faculty of the Computer and Information Sciences Department also began to design a computer literacy program that would complement the work of their science colleagues.

In 1981 IBM, the first and largest donor for curriculum support, pledged $200,000 to develop the Iona College STL program. The STL program was developed along three themes: health, energy, environment. Each theme was to be composed of four modules of 1.5 credits each. Simultaneously, two 1.5 credit modules designed to teach computer literacy were designed. In May of 1982, Iona's Academic Senate voted to establish a new core curriculum including a six credit STL requirement and a three credit computer literacy requirement. The computer literacy component was folded into a standard three credit course to be offered each semester. Experience with the modules revealed that a 1.5 credit course per semester was difficult for the students to adjust to and incorporate in a student's schedule. Modules were coupled so that two 1.5 credit modules could be taken back-to-back each semester and eventually combined into standard three credit courses.

Iona became increasingly aware that the successful implementation of the STL curriculum had to be a campus-wide effort. In the Fall of 1983, a Science and Technology Fellows program with a science faculty leader and six liberal-arts/business faculty was initiated. In the Spring of 1985, Iona applied to the Alfred P. Sloan Foundation for further support in the development of its curriculum and was awarded a grant for preparation of curriculum materials and the dissemination of these curriculum ideas and strategies to other colleges. Grants from the American Can Company and GTE supported another Iona STL initiative, the Science and Technology Lecture Series, to stimulate diverse audiences within and without the community to a greater understanding of the effects of Science and Technology. During 1986, the Surdna Foundation granted a second award to support Iona's STL effort in developing its environmental sequence to a greater extent and furthering its efforts to disseminate its curriculum materials to other colleges. In the Spring of 1987, the Sloan Foundation awarded Iona College a second grant under its New Liberal Arts Program.

Philosophy

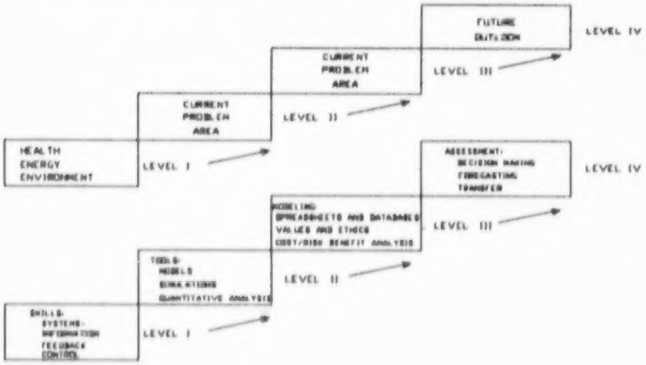
The curriculum itself is a synthesis of many elements and techniques. They are unique in the way they are combined to enable all students at Iona to develop approaches to solving problems and making decisions on scientific and technological issues and to fulfill their roles as concerned and aware citizens. The philosophy of the program envisions a model in which science and technology are integrated into the daily life of the students, the college and the community. The basic sciences, biology, chemistry, physics, computer and information sciences, psychology, and mathematics form the core of the dynamic programs in energy concerns, environmental maintenance, and health issues. Basic and applied research by the science faculty in the three areas provide the programs with credibility and a resource from which all three interdisciplinary areas draw their inspiration.

Scientific and Technological Literacy

Six credits in Scientific and Technological Literacy (STL) courses are required as part of the college core of each Iona student. After choosing from among the health, energy, and environment themes, the student completes in sequence, two three credit courses, each of which is divided into two modules. The program is supported by the faculty of the Departments of Biology, Chemistry, Physics and by the faculty of cooperating departments such as the Psychology Department. The major difference between the present STL program and previous offerings in science for the business and liberal arts students is the emphasis that is placed on process as opposed to content. In addition, the activities component in each module provides a "hands-on" experience for the students which helps them develop an appreciation of the role of experimentation in science.

Each theme of four modules seeks to achieve the same goals although the subject matter may be different. In the first module the emphasis is on problem solving with an accompanying review of basic and necessary science concepts and terminology. Problem solving means different things to different people. What is a problem? Depending on one's training and experience different definitions may be given. Each answer and definition conditions the approach a person uses to solve problems. In the

GENERAL PLAN OF THE IOWA SCIENTIFIC AND TECHNOLOGICAL LITERACY SEQUENCE


FUTURE OUTLOOK
LEVEL IV
CURRENT PROBLEM AREA
LEVEL III
CURRENT PROBLEM AREA
LEVEL II
HEALTH
ENERGY
ENVIRONMENT
LEVEL I
ASSESSMENT:
DECISION MAKING
FORECASTING
TRANSFER
LEVEL IV
MODELING:
SPREADSHEETS AND DATABASES
VALUES AND ETHICS
COST/RISK BENEFIT ANALYSIS
LEVEL III
TOOLS:
MODELS
SIMULATIONS
QUANTITATIVE ANALYSIS
LEVEL II
SKILLS:
SYSTEMS:
INFORMATION
FEEDBACK
CONTROL
LEVEL I

introductory modules an attempt is made at the beginning to have the students recognize some of the difficulties that arise in defining a problem. Simple concrete examples are used to demonstrate different strategies for solving problems. Ultimately, scientific and technological approaches to problem solving are developed with the goal of having students at least recognize and understand the many approaches and, perhaps, use them operationally.

The systems approach involving concepts such as input and output, information, feedback and control is used. The concept of a model and modeling is central. Scientific content is introduced in terms of the illustrative examples used within each theme. Fundamental scientific models of matter, energy, and life are developed in class and reinforced in outside readings. These readings are taken from textbooks and from other sources such as: magazine articles, newspapers, and from scientific publications. Requiring reading in such media serves to familiarize the students with, and also gives them the confidence to read, such articles.

ENVIRONMENT	HEALTH	ENERGY
Ecological Principles	Nutrition and Diet	Energy Conversion Principles
Earth, Air, Water Resources	Anatomy	Solar Energy
Acid Rain	Cardiovascular systems and exercise	Photo Voltaics
Water Conservation	Artifical Organs	Bio mass energy, alcohol
Solid Waste Disposal	Structure and Function of the brain	Electricity
Waste Water Treatment	Biofeedback and behavior modification	Electric Power Technology
Radioactive Waste Management	Dialysis and Organ Transplantation	Bioelectricity
Lead in the Environment	Genetic Therapy	Nuclear Power
Predicting and Controlling Weather		Energy for Transportation

A sampling of the possible topics of study within the STL themes.

The second module constituting the second half of a three credit course continues the development of science and technology in a vertical structure. More models and rudimentary simulations are introduced. Quantitative methods are introduced along with some general characteristics of technology.

Simultaneously, in their laboratory work, students are learning to gather data, organize it and present it in tabular and graphical form. Elementary hypotheses are formed, tested and conclusions are presented and discussed. Scientific measuring skills, computational skills, graphing, reasoning, and critical thinking are emphasized in the laboratory exercises in the first two modules. Laboratory reports are required each week with reports done on the computer using wordprocessing packages.

The emphasis in modules three and four, the second three credit course, is on decision-making. It is within the last two modules that simulations, quantitative modeling, and computer models are more fully developed. LOTUS 1-2-3 and dBASE III Plus are computer tools used by the students in analyzing appropriate problems. Flowcharting, probability, decision trees, and systems analysis are employed. Topics involving cost-benefit analysis and risk-benefit analysis are introduced. Technology assessments in formal and informal applications are considered. Values and their role in ethical decision making are treated. Complex decisions involving open-ended problems are analyzed in examples such as: kidney transplants, genetic engineering, radioactive waste disposal, maximum exposure limits to radiation, carcinogens, etc.

It is in the last two modules that the laboratory activities, which depend on skills acquired in the earlier modules, emphasize applications to everyday problems. They are designed to teach students to transfer and apply knowledge and skills gained in the six credit STL sequence to other areas in their college studies and their everyday lives.

S&T Fellows

Since its inception in the Fall of 1985, the S&T Fellows program has enrolled thirty key faculty members from the liberal arts and business programs in a seminar designed to inform them about science and technology through a study program, with professional applications within their own disciplines. It also provides the non-science participants with an understanding of Iona's STL curriculum, its format and philosophy. Most non-science faculty members, although experts in their fields, need a structured program for a fuller understanding of science and technology as it affects their lives and their academic disciplines. Participants follow a schedule of bi-weekly seminars in which course projects and assigned readings are discussed. In the Spring semester, the Fellows prepare a portion (about 10%) of one of their courses, which they are teaching or will teach the following academic year, to incorporate some issues or content from science and technology. At the conclusion of the seminar the Fellows prepare a report on their experiences, offer recommendations for subsequent programs and suggest faculty for the next program. The S&T Fellows program is a part of the campus-wide effort to extend the goals of the S&T program into the wider college community and produce a positive campus environment for accomplishing those goals.

STL Lecture Series

The lecture series is designed to stimulate diverse audiences within and without the college to a greater awareness and understanding of the effects of science and technology. Since the Fall of 1985, eight presentations have been made to the community covering a variety of topics: space-borne computers, space and space shuttles, film technology, environment and health, the strategic defense initiative, technology of cardiac care and diagnosis, the nature of science, computers and music.

The lecture series is philosophically linked to the STL program in that it uses another avenue of approach in bringing students, the college community, and the outside community to a greater awareness of issues involving science and technology. Encouraging student attendance initially gives them an experience which may develop into interest and concern. On future occasions, they may attend on their own.

Connections

Iona College's core curriculum consists of 54 required credits out of 120 credits (arts and science students) or 126 credits (business students) grouped into five areas:

I. Humanities (English, history, philosophy, religious studies). II. Social Science (economics, political science, psychology, sociology). III. Science and Technology. IV. Natural and Symbolic Language (mathematics, computer science, modern or classical languages). V. Communication Skills (English composition, speech and communication).

The college core curriculum is the program of studies designated by the faculty as essential for providing students with the necessary resources for initiating life-long engagement in the study of liberal arts. All courses are designed to help Iona students achieve those goals which derive from Iona's educational philosophy.

The STL program as a part of the college core endeavors to identify bridges to other core disciplines. Topics treated such as: abstract reasoning, problem solving, systems approach, role of cultural biases, history, and geography in problem solving, using computer skills and quantitative methods which are treated in other core areas are reinforced in the STL program as it strives to achieve its own goals. By its very structure the STL program provides an integrative experience for the students at both a skills level and a conceptual one.

Works in Progress

A fourth STL theme directed to the interests of business students, the refinement of the present modules, the development of a new generic module, the continuation of the S&T Faculty Fellows program, the development of a set of faculty-authored readings and an extension of the dissemination process to communicate with an additional number of colleges, are all part of the effort to develop an STL program that will enable Iona's graduates to interface with a world that is becoming ever more challenged by the issues of science and technology.

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SCIENTIFIC AND TECHNOLOGICAL LITERACY: A MODEL FOR THE LABORATORY COMPONENT

Warren Rosenberg

Introduction

The progress of science and technology holds primary responsibility for the accelerating rate of change in our society. Many liberal arts institutions now recognize an obligation to provide students with the ability to inform themselves and organize facts about contemporary issues involving science and technology and with the confidence neeeded to comprehend and contribute to public discussions about technological matters.

Historically, non-science students in most liberal arts institutions have satisfied their undergraduate science requirement by taking either lower level courses within one of the major science disciplines or "watered down" science courses designed to be less rigorous than those intended for students majoring in the sciences. Often, these latter courses do not include a laboratory component. When laboratory experiences are offered, they tend to be similar in nature to those geared towards the science major. While adequate for providing the beginning science student with an introduction to laboratory skills in a specific discipline,these activities fall short of accomplishing the goals stated above.

In developing courses for the non-science major, the emphasis should therefore be on developing new laboratory activities which present science and technology in the context of human affairs while providing students with the analytical, quantitative and problem solving skills needed to understand, be involved with and benefit from technological change.

The Curricular Context at Iona

Iona College has developed a sequence of laboratory exercises for courses in each of three thematic areas - health, energy and the environment. The exercises form a major component of a set of courses in Scientific and Technological Literacy (STL), which is committed to providing concrete and practical learning experiences to students in lab sections of substantial size. The STL experience consists of a year long sequence of course modules consisting of two hours of lecture and two hours of laboratory per week for three credits per semester. Students spend the entire year studying one of the thematic areas.

The lecture and laboratory periods allow students to explore the available and proposed technologies applicable to solving present and future societal problems in a self selected thematic area. Students are offered the opportunity to participate actively in the analysis of these technologies with respect to their impact on social, moral, ethical and economic aspects of society as well as to assess their efficacy in correcting the underlying problem.

The primary objectives of the laboratory experiences are to develop problem solving and quantitative reasoning skills, an understanding and appreciation of the various methods of modeling a situation for subsequent evaluation, an ability to use computer applications and the sensitivity to identify and incorporate value issues into technological decisions and applications. The scientific content, while significant in detail, is held secondary to the above. These students need not be trained in the skills required of the scientist but rather, with those required of an informed and participating citizen.

Introductory laboratory exercises are designed to introduce students to methods of measurement, statistical analysis, modeling and computer applications. Subsequent laboratory experiences allow students to apply these skills to the investigation of scientific principles and technological applications in a specific thematic area. The final laboratory experiences involve the use of models to perform forecasting, cost/benefit and risk/benfit analyses, technology assessment and the integration of value issues.

Some Specific Examples

Environmental Technologies

In the midcourse modules of the environment theme, a series of laboratory exercises challenge students with the problems of solid waste disposal, water and air pollution. As an introduction to the magnitude of the municipal waste problem, students inventory their own personal contribution to solid and sewage wastes. In a subsequent laboratory a study is conducted of the rates of decomposition of various materials; paper products, natural and synthetic fibers, and plastics in soils ranging from dry sand to moist, rich organic soil. This activity is coupled with lectures on the methods and hazards of disposal through sanitary landfill along with discussions on the need to reduce solid waste and the alternatives available for doing so. A case study is made of the technology, economics and politics behind the local county government's (Westchester) decision to close the county landfill and contract with a private firm to build and operate a waste-to-energy incinerator.

In a laboratory investigation of the technologies involved in water purification, students are provided with a wastewater sample of known volume containing dissolved and suspended organics, suspended inorganics, ions and bacteria. Semi-quantitative tests are made in the laboratory to confirm the presence of contaminants, bacteria and to measure turbidity. Students are presented with the challenge of devising and performing the most cost effective method of cleaning the water sample. The treatment method must consist of no more than three options chosen from; gravity fed screen filtration, forced fiber filtration, sedimentation, coagulation/floculation/precipitation, charcoal absorption and chlorination. Each treatment method is rated by efficiency and contaminant(s) removed and is assigned a cost per unit volume of water treated.

Students are given the role of municipal planners and charged with cleaning the water sample as best as is possible at the lowest cost. The final score is determined by an equation which weighs the cost of treatment and volume of treated water obtained (cost per ml of treated effluent) and the quality of the water before and after treatment. The students have prior knowledge of the equation and of the scoring criteria and may use this knowledge in selecting their treatment method. Students most often select a treatment method which results in the largest volume of treated water at the lowest cost and rarely select a method resulting in the highest degree of purification. A discussion follows on why industry and municipalities often choose the same route and of the necessity for having, and mechanisms of enforcing, water purification standards. A field trip to a local municipal sewage treatment plant follows (we have recently had difficulty with this due to insurance cosiderations).

In a study of airborne pollution students construct and employ the use of a dustfall bucket and sticky tape collector to sample and measure airborne particulates. Wind direction and velocity is measured and, along with local maps of major roadways, municipalities and industries, is used in identifying possible sources of contamination. The adverse impact of airborne pollutants on human health, natural ecosystems and architectural structures are discussed in lecture sections as are the technological interventions available for reducing airborne contaminants.

Health Technologies

In the last module of the health sequence theme, a unit presents students with a set of situations, both lecture and laboratory based, in the areas of end stage renal disease, dialysis and transplantation. As a prelude to discussions on hemodialysis, peritoneal dialysis and portable artificial kidneys, students conduct laboratory studies modeling diffusion, osmosis, dialysis and active transport. Diffusion is first presented as a mathematical model. A physical model is then constructed from dialysis tubing and students explore the relationship between diffusion rate, concentration, temperature, surface area and molecular size, confirming predictions based upon the mathematical model. Their studies enable them to confirm the design logic of dialysis cartridges and various dialysis therapies.

Active transport within the living kidney is studied with the aid of nephron tubules isolated from the goldfish kidney. The role of animal surrogates in biomedical research and the ensuing ethical implications are discussed. Data obtained through the study of these models are used to explain the development of today's treatment methods (hemodialysis, peritoneal dialysis, transplantation) and to explore the technical feasability of future treatments (portable artificial kidneys, oral sorbents, xenografts).

The unit also explores the methods of diagnosing renal disease. Students are assigned fictitious patients and provided with brief medical histories and simulated urine specimens. Laboratory activities involve qualitative analysis of the urine samples and the use of a mock expert system program to diagnose disease. Students then participate in an exercise in which they role-play as family members, physicians, and hospital administrator, deciding whether a homeless alcoholic, noted celebrity, or self-employed entrepreneur should receive the kidneys of a brain-dead donor. Students are provided with data as to tissue type matches, longevity projections for each patient given treatment by dialysis versus transplantation, financial and insurance data on each patient and information as to the cost of each procedure.

Extensive discussions are conducted regarding quality of life issues on the various therapies and of the problems inherent in allocating limited medical resources and obtaining donor organs.

In the Iona model, all STL laboratory activities are associated with measurement and quantifiable topics, stress active involvement and look at both the scientific and human sides of technology.

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SEEKING TECHNOLOGICAL PERSPECTIVE IN THE UNDERGRADUATE CURRICULUM

Kenneth R. Stunkel

The purpose of this essay is to relate one college's attempt to find a coherent place for technology education in the undergraduate curriculum. The experience showed that more can be done than feature courses taught by scientists and engineers. Technology education can, and perhaps should, entail mobilization of faculty across the disciplines. But this is not a likely occurrence without deliberate effort to build a foundation of mutual understanding and agreement. A mature conception of technology education suggests that organized faculty dialogue and development must precede the instruction of students. An effective way of getting started is to assemble faculty from a spectrum of disciplines in a prolonged seminar to discuss, clarify, and seek consensus on the philosophy, content, and strategy of technology education for undergraduates.

A Seminar in Search of Technological Perspectives

A group succeeded in coming together and reaching a consensus at Monmouth College in New Jersey, a "comprehensive" institution with enrollments of about 4,000 students, a bit less than half of whom are undergraduates. In the past three years issues of technology, society, and values in the curriculum surfaced as an institutional goal. There are two immediate settings, both supported by grants from agencies in New Jersey(1). The first is a yet uncompleted revision and expansion of the undergraduate general education program, which includes courses and devices for educating students in technology related issues. The second, and the focus of this paper, was a broad based seminar on technology and society which met from September 1987 to January 1988. The membership (14 altogether) included academic administrators, faculty across the disciplines, and people from business and the secondary school system. The purpose was to read articles and books dealing with questions of technology, society, and ethics, to interact with distinguished speakers in established technology programs at other institutions, to serve as a resource group for the College, and to spell out workable criteria for the development of technology oriented courses across the curriculum. Seminar participants, who committed themselves to weekly meetings on their own time, underwent a dramatic transformation of consciousness as a result of readings, discussions, and construction of draft course syllabi for scrutiny by the group. A collective assault of this sort on the place of technological education in the curriculum turned out to be a promising means of curricular change and faculty development at an institution with tight resources and a small instructional staff of about 155.

All discussion about technological education or "literacy" in the seminar tended to collect around much the same questions. Is it appropriate or necessary to focus resources and faculty on technology education? What is to be meant by "technology" and what is the scope of "technological literacy?" Who is fit to teach courses in the subject. If a traditional notion of expertise is not the criterion for staffing and faculty are sought across the disciplines, how are they to be trained and developed. If technology education is not to become a mere add-on or isolated program, how can its perspectives be diffused through the curriculum?

The Question of Need

The need for technological literacy was the easiest question to settle. Monmouth College has no specific courses in technology and society, not even one in the history of technology, nor is there any programmatic, departmental, or institutional policy regarding such instruction. Monmouth College students graduate with little knowledge of technology related issues, much less being able to think critically about technological systems or public policy alternatives. It was agreed that something ought to be done.

The technological ocean on which we sail is mostly taken for granted, as recent closing of the shamefully neglected Williamsburg Bridge in New York illustrates. Technological resources have become a major driving force of the age, but frequently without benefit of user understanding or responsible concern. Furthermore, every piece of technology, from an electric can opener to a space shuttle, is a control system with certain obvious uses and benefits. Less apparent is the ease with which technology can displace human choices and produce unwanted effects, including serious damage to health and environmental safety, the disastrous breakdown of technological systems themselves, and weakened democratic values. Lewis Mumford reminds us that "while any new technical device may increase the range of human freedom, it does so only if the human beneficiaries are at liberty to accept it, to modify it, or to reject it."(2)

Preparing men and women for thoughtful choices about the profusion of technological innovations each year should be a major task of higher education. While the situation today is better than it was a decade ago, most students who acquire baccalaureate degrees still remain innocent of useful technological perspectives. To that extent the structure of higher education is archaic in the last quarter of the twentieth century, especially in institutions with strong commitments to liberal study where the word "technology" has negative overtones of vocationalism. Courses have been introduced at several hundreds of schools, but they tend to be add-ons rather than integral to liberal studies, narrow in scope, and often identified with the computer.(3) Thus the fit between what is done and what needs to be done is very poor at most places. Corrective action is not easy to come by. Even if the faculty of a college acknowledges the need for curricular change and a shift in priorities, there are tough questions to be resolved -- what is to be taught, how, by whom, and to what precise end?

The Question of Definition and Scope

In the weekly seminar it took time for a conception of technology and technological literacy to emerge. Simplistic definitions are easy to come by and agree upon, such as J.K. Galbraith's view that technology is applications of organized knowledge to practical tasks, or John Truxal's view that it is applications of scientific knowledge to human ends. It is easy enough to distinguish theoretical interests of science from pragmatic interests of technology, to see that science seeks to understand nature while technology aims to control and modify it, or to grasp that science is complex because it deals with nature, and that technology is relatively simple because it has been designed by people.(4) The array of "definitions" discussed had a cumulative effect of dulling the mind and obscuring the issue. In the case of technological literacy, some seminar members argued that it should encompass nothing more that an account of how structures, machines, and processes work. One consultant characterized it as highly specific kinds of problem solving on the engineering model.(5)

The seminar eventually agreed on a more intricate model which includes (a) systems analysis as a key both to understanding technology and relating it to other systems --

political, economic, social, and environmental; (b) the intrinsic association of technology with values and ethics; and (c) technology as a phenomenon which is understood best not just as a means of solving problems, but also as a force in politics, social life, aesthetics, and ethics which must be understood if one is to be "literate" about it. There was a surprising consensus about systems analysis, or systems thinking, which meant nothing to most seminar participants at the beginning. A seemingly isolated technological artifact, say the reactor of a nuclear submarine, can be understood at ascending levels of complexity. At each level one thinks about the artifact within a model governed by certain questions: what is to be accomplished, by means of what resources, and with what anticipated outcomes? Purely technical problem solving at lower levels entails determining what is intended (inputs), how it is achieved (processes), and what actually results from the effort (output), with results modifying intentions through a feedback loop.(6)

Seminar participants came to understand that cost-benefit analysis is a form of systems thinking, but an effort was made to avoid saying the two are equivalent. The reason is that cost-benefit problem solving, in which one weighs losses against gains and tries to minimize the former and maximize the latter, must be seen as decision making in which ethical and social impacts can be masked or ignored. The emphasis on measurable or marketable factors usually exalts the bottom line without taking into account who ends up paying the costs, nor does the bottom line tell one clearly who gets the benefits, or what is right or desirable. Thus cost-benefit analysis in technology education courses, while essential, should be presented as part of a more comprehensive scheme of systems analysis in which non-measurable factors are taken into account, those who profit and pay are sorted out, and effects beyond the immediate are identified.

If technological literacy entails systems analysis and problem solving, and if those kinds of activities are central to understanding the nature and uses of technology, what about the range of connections with varied social phenomena and the past? Should any good course in technology and society have a solid historical dimension? Lewis Mumford argues that technology involves more than tool making and using, and that understanding humankinds' relationship to technology even in that narrow sense requires explorations into human nature and strongly developed historical consciousness. A few seminar participants said that technological education should confine itself to how things work and to problem solving because of limits on time. John Truxal pointed out in a lecture to the group that successful, effective technology courses must be interesting to students, who care more about the present than the past and change interests unpredictably. Thus issues of energy and urban transportation have lost ground with students at Stony Brook, while space, medical, and communication technologies are riding high. In that context, would it be wise to spend time on technologies of the ancient world or early industrial England?

The two historians in the seminar took exception. Since technology is associated intimately with institutions, social values, the contemporary state of scientific knowledge, and big historical occurrences such as wars, trying to talk about it in isolation contributes to the mindless fragmentation good technology education ought to combat. This tension between the present and the past is not easy to relieve. The problem tends to be exacerbated by the disciplinary commitments of academicians, which can promote the kind of ahistorical attitudes observable in so many students.

In the end, it was agreed that more stress must be placed on the present than on the past. If technology education is to be helpful to thoughtful citizen involvement in public policy debate and decision making, bio-engineering and nuclear power, the space shuttle and chemical synthetics, are better targets for analysis than Watt's steam engine or the turn of the century wireless. On the other hand, there was agreement, though sometimes grudging, that historical perspectives must be introduced to avoid reductionism (the "nothing matters but now" syndrome), the isolation of understanding in a few machines, structures, or processes, and the fallacy that components are more important than their relationships in a system.(7)

One of the most provocative issues discussed was whether a course in technology and society should address the nature of technological rationality itself? Should it be assumed that technology is value free? Is it merely a neutral instrument, a means to valued ends chosen in other frames of reference? Is technology based on value judgments intrinsic to itself? The seminar was persuaded that technology has value presuppositions and cannot be regarded as neutral or objective in the sense of being value free.(8) Consequently it is not sufficient to say that technology is related to values. The presuppositions of technological rationality imply a value system and generate a peculiar field of vision in which objects are perceived and distanced. They are viewed as subjects of control and manipulation. The means of control is reduction of their qualities to quantities, and decision making is based on optimization of gains over losses, commonly stated in numerical terms. Should this way of seeing objects be rejected, it would be tantamount to rejecting technology itself. Friendship or aesthetic contemplation are antithetical to notions of manipulation, quantification, or optimization. Their values would be lost should they become objects of technological rationality. Thus objects are detached from their own goals, purposes, desires, or motives, which lays the groundwork for manipulation in the quantitative mode (what Lewis Mumford has called "quantification without qualification"). Another way of phrasing this point is that technology, or technological rationality, is preoccupied with its own ends and not those of the object. If this argument has merit, it would be prudent to alert students that technology is a universe of discourse with its own presuppositions about worthy ends. Technological rationality seems to invite potential conflict with any value system in which control, quantification, and optimization are perceived as irrelevant or undesirable.

The Question of Competence

A criterion for good technology courses is that faculty must know what they are talking about. A seminar participant observed that you can teach only what you know. How, then, can people in history, philosophy, sociology, and literature hope to teach courses in technology? Where are the technical knowledge and skills to come from? How can the fragmentation of academic environments into multiple departments, disciplines, and sub-disciplines be overcome, so that technology education is not a monopoly of scientists and engineers by default? How can a faculty cope with professional narrowness, the mystique of expertise, and the instinct of territoriality? It is inevitable but also unfortunate that technology education routinely conjures an image of highly specialized technocrats. The sensitive issue for disciplines is: who is to teach what and how?

The question of who was answered quickly in the seminar. Monmouth College cannot afford to hire people for a separate program in technological literacy. The upshot is that technology education must rely on the energy and resourcefulness of existing faculty. The task cannot be left to the scientists and engineers either. Teaching and other professional commitments limit the time they can give to general education or to technology and society in the curriculum, and more than a few are just not interested. Therefore faculty across the disciplines must be recruited. The institutional response must be faculty development supported by incentives -- load reductions, stipends, funds for materials (books, slides, demonstration kits, and the like) workshops, and merit pay. Grant money must be sought to help pay the bills.

The seminar demonstrated that non-scientists and non-engineers can become valuable champions of technological education. An advantage of using diverse faculty is that technology education will have representatives in more than one department or discipline, and it is less likely to go the way of many black and women's studies programs, which have ended up cut off from the rest of the curriculum in special programs and institutes. A second advantage is that technology education is not associated solely with engineers, scientists, and technicians, but draws into its domain intelligent, well motivated, curious, resourceful men and women from the humanities and social sciences who can expand the range of pertinent questions and insights. Needless to say, everyone has to do homework, absorb fresh, unfamiliar knowledge from other disciplines, and acquire new skills. Bringing the engineer and the humanist together can be mutually enriching. They learn from one another and higher education is the better for it.

Guidelines for Courses in Technology and Society

After a full semester of reading and discussion, the seminar was polled for standards that ought to apply to technology education courses taught at Monmouth College. Here is the outcome.

1. Systems Thinking and Analysis. All students should become familiar with the general systems perspective as it applies to technological artifacts and events. The terminology used should include control network analysis, decision trees, and risk-benefit analysis. The study and use of systems analysis should include a critical look at its proper scope and limitations in relation to technological decision making and problem solving.

2. Technological Rationality. In the process of defining or characterizing technology, it should be distinguished from science, art, and other human enterprises. The common view that engineers and technocrats think in a value free mode should be challenged and examined.

3. Appreciation of Values. The close association of technology with value systems (religious, aesthetic, social) should not be neglected. This concern can take the form of looking at who the technology serves or fails to serve, how technological change may impact for good or ill at local, regional, and even global levels. There should be reference to the value conflicts produced by technological change. What is the price to be paid, and by whom?

4. Historical Perspective. Students should have some exposure to great watersheds of technological change in the human past and their effects on society. Where appropriate, structures, machines, or processes under discussion should be given some historical context.

5. Artifacts in Operation. Students must be provided with "hands-on" exercises and experiences. They must work on real problems and discover through practice how technological problem solving takes place.

6. Interactions of Society with Technology. There should be discussion and exercises which invite students to grasp and appreciate the interplay of technology with politics, economics, and social values. There should be some critical exploration of how technological options might affect social outcomes in the family, in local communities, and on up through regional, national, and global levels.

7. Democratic Decision Making. A successful technology course should prepare students for more intelligent participation in decision making. They should be able to read and interpret technological literature and arguments for the general public, critique various policy alternatives, and present their own views with a critical regard for evidence and the consequences of a choice.

A number of courses developed from these guidelines by seminar members and other faculty will become junior-senior level "perspectives" courses and be available to students as part of a required unit in the College's general education program. A half dozen or so technology and society modules will be assembled from some 2,000 slides and a set of lecture notes used at Princeton University by David Billington, who teaches "Structures and the Urban Environment" for non-engineering undergraduates.(9) The modules will consist of some 40 slides each, with supporting explanation and a set of engineering exercises for students. The modules will be usable across the curriculum in a variety of courses - e.g., American History, Urban Sociology, Art History, Western Civilization. Technology education will become part of general outcomes assessment now under development.

While these initiatives are going on, the seminar will function as a resource group to the faculty and the College, and some members of the seminar will lead their own workshops to prepare faculty for inclusion of technological perspectives in their courses. All of this will have to be done well and with care to succeed, and it will not be easy, but perhaps a little *hubris* on behalf of a many sided technology education program is just the ticket.

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1. For information regarding the Faculty Seminar on Technology and Society at Monmouth College (materials, consultants, agenda, membership, syllabi, future outcomes, etc.) contact Dr. Saliba Sarsar, the seminar leader, at Department of Political Science, Monmouth College, West Long Branch, NJ 07764. The $50,000 grant from the Department of Higher Education in New Jersey that supported the entire project was conceived and written by the Provost of the College, Dr. Eugene Rosi.

2. Lewis Mumford, *The Myth of the Machine: The Pentagon of Power*, New York: Harcourt Brace Jovanovich, 1964, p. 185. Cf. Peter Drucker, who urges that our most pressing difficulty is seeing that technological change and its supporting institutions embody the values and purposes we want and promote human freedom and dignity. "The First Technological Revolution and Its Lessons," *Technology and Culture 7*, 2 (Spring 1966).

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DEVELOPMENT OF A COMMUNITY ORIENTED COLLEGE LEVEL TECHNOLOGICAL LITERACY COURSE

Robert J. McCallum, Alvin F. Shinn, and Kenneth A. Job

Introduction

During the 1986-87 academic year a course in technological literacy was developed and taught at the William Paterson College of New Jersey, a liberal arts state college. This paper provides a discussion of the 1) objectives, 2) description, and 3) assessment of this course.

The three credit course, *Technology and Society,* was initially offered as an upper level course in the Environmental Studies Program but will, in the future, be offered as an upper level elective in the General Education Program. The course was team taught by the three authors whose specialties and interests include chemical thermodynamics and energy issues (McCallum), ecology and radiation (Shinn), and the history of technolgy (Job). With few exceptions, all three faculty members attended each class. In addition to two 75 minute lectures per week, the course met on five Friday afternoons during the semester for field trips and other special classes. Also, the entire class went to the Smithsonian Institution in Washington for a weekend field trip. The initial offering of the course had ten students enrolled, all juniors and seniors. Eight of the students were either Biology or Environmental Studies majors; one was an English major, and one student was undeclared. The course was also audited by one of the college's librarians interested in developing the college's holdings in technological issues.

Course Objectives

There were three kinds of objectives for this course: A) Understanding, B) Skills and C) Attitutes. More specifically these objectives include:

> A) To give students an understanding of the appropriate application of scientific concepts, principles, laws, and theories to the study of some specific tecnnolgy, i.e, to make the technology understandable.
>
> B) To enable students to utilize logical processes in solving problems and making decisions, and then to use these skills in studying technological issues.
>
> C) To cultivate within students an appreciation for the role of technology from a historical perspective and to promote an awareness and confidence to address technological issues as active and informed participants in our technologically-based society.

In order to meet these goals, we constructed a course where an experiential component would be given primary attention. Our course using field trips and workshops extensively would not deal with technology as an abstract issue but as an integral part of a student's personal and community life.

Course Description

William Paterson College is located next to the City of Paterson, the first planned industrial city in the United States. The Great Falls of Paterson was the impetus for this industrial development by Alexander Hamilton and others. The historic raceway system associated with Paterson's rise to industrial prominance still remains fairly intact. As our course began, the Paterson Falls hydroelectric power plant, which had been idle for two decades, was nearing the completion of its renovation and, in fact, went on line during the semester. Water power, Paterson and its Great Falls became the foci of our course. The falls was minutes from campus. It offered a historical perspective, and yet reflected modern technology with its new hydroelectric facility. Water and hydroelectric power were fairly simple technologies to consider in terms of the underlying science. The nearby Paterson Museum provided more material for this study. The Edison National Historic Site, Edison's Laboratory, in nearby West Orange, NJ, also provided an additional resource for our topic. Finally, the opening of the Engines of Change Exhibit at the Smithsonian Institution during our course afforded another opportunity to study water power as well asother appropriate technologies.

The course was divided into three main sections, each area taught by one of the contributing faculty. Each section used approximately one-third of the semester. These main areas were: 1) History of technology, 2) Energy and electricity, and 3) Technological Assessment.

Technology and Society Course Outline

I. Introduction and overview of the course.

II. History of Technology

- A. Video clip (the thrown club) from Kubrick's *2001: A Space Oddysey* - Nature of tools
- B. Artifacts: Sumerian tablet, Colonial glass bottle, Iron "Bar Fly", Mayan clay whistle
- C. Review of common elements of culture stressing technology (defined); see Cultural Conceptual Framework)
- D. James Burke's *Connections: The Trigger Effect* [videorecording]
- E. Creativity and technological advancement
  - 1. Chevron filmstrip *Creativity: The Human Resource*
  - 2. Creativity exercise
- F. Nature of civilization - the technological base
  - 1. Contrast among technical and non-technical societies
  - 2. Develop definition of civilization (based, in part, on technology)
    - a. Draw on Burke tape and Creativity filmstrip
    - b. "Urban Revolution" concept (Childe)

G. Technology of the Ancient World (Western Civilization)
   1. Overview of technologies and civilizations of Sumer, Egypt, Greece and Rome
   2. Basic issue: apparent lack of technology in ancient world
   3. Examples: Ancient Greek navigational device, ("computer"), Hero's steam engine, Archimedes' screw, architecture (arches, doors, fountains), coin dispenser, Punic warship, underwater archeology (stressing interchangable parts)
   4. Role of "technologist" in ancient society

H. Technology and the Medieval Period
   1. Social attitudes and technological development
   2. J. Bronowski's *The Ascent of Man: The Starry Messenger* [videorecording] - The Trial of Galileo
   3. Technology and freedom (Lysenko controversy)

I. The Industrial Revolution
   1. Shift from Mediterranean
   2. The English Industrial Revolution - Why, where, who?
   3. J. Bronowski's *The Ascent of Man: The Drive for Power* [videorecording]
   4. The Industrial Revolution in America - Why, where, who?
      a. Basic Power sources - muscle, wind
      b. Water Power (Burke's *Connections: Faith in Numbers* [videorecording])
      c. Role of "technologist" during Industrial Revolution

J. Waterfalls - types, geology of formation (computer simulation)

K. Paterson and the Great Falls
   1. History of Paterson and SUM (Society for Useful Manufacturing) guest lecture and tour by Grace George
   2. The raceway system
   3. Tour of the raceway system and Paterson Museum
   4. Hydroelectric use of Great Falls

L. Inventing the future
   1. Sources for predictions
   2. Recurrent themes in history of technology

M. Field trip to Washington, D.C., Smithsonian Institution, National Museum of American History, (specifically Engines of Change Exhibit) and National Air and Space Museum

III. Energy and Electricity

A. Energy
   1. Definition of terms, types, equations
   2. First and Second Law of Thermodynamics
   3. Water Power - sources, advantages, disadvantages, equations
   4. Quantitative energy problems
   5. Hydrogen Economy (there was some thought of using the Great Falls hydroelectric plant to produce hydrogen)

B. Electricity
   1. Chronology of electical technology (with particuular attention to independent but concurrent developments)
   2. Field trip to Edison's laboratory, West Orange, N.J.

3. Definition of electrical terms, units, equations
4. Electrical devices (description and function) - Emf sources (batteries, generators) switches, relays, resistors, capacitors, transformers, motors, and semiconductors (diodes, transistors, LEDs)
5. Circuits
    a. Calculating resistance, current, and voltage in simple series, parallel, and more complex circuits
    b. Electronic kits - Building circuits demonstrating functions of batteries, switches, resistors (series and parallel), capacitors, transformers, diodes, LEDs , and transistors; practical circuits (burglar alarms, reflex testers, synthesizers, transmitters, receivers, etc.)
6. Paterson Great Falls hydroelectric facility
    a. Field trip
    b. Guest lecture - John Topalian, Paterson City Engineer
7. Superconductivity and its implications for the future
8. Francis Ford Coppola's *The Conversation* - technology and morality

IV. Technological Assessment

A. Overview of need for technological assessment

B. Office of Technology Assessment

C. Case study of a successful technology; the DC-3, *The Plane that Changed the World,* [videorecording]

D. Tools of technological assessment
    1. Probability
    2. Decision trees
    3. Dynamic Programming
    4. Risk and Cost-Benefit Analyses

D. Assessment of hydroelectric facility at Great Falls

E. Course assessment
    1. Written
    2. Student dialogue with outside evaluator, Prof. Steven L. Goldman

Evaluation of students:

1. Three hour examinations including circuit building practicum (75%)
2. Workshop and homework assignments (10%)
3. Field trip reports (10%)
4. Electrical assignment (fixing an electrical appliance) (5%)

This syllabus represents several significant changes in the curriculum as originally proposed:

1) The Washington trip was also to include a visit to the Office of Technology Assessment. Student scheduling necessitated a weekend trip when the office was closed.

2) The viewing of the film, *The Right Stuff,* to be seen in conjunction with the trip to the Smithsonian's National Air and Space Museum and as a counterpoint to *The Conversation,* was eliminated due to lack of time.

3) A careful assessment of the new Great Falls hydroelectric facility was impossible due to limited time and lack of hard data.

4) Lack of time sharply curtailed time spent on Risk and Cost-Benefit Analysis.

5) Computer aided decision analysis was eliminated due to lack of appropriate level software.

Course Assessment

Our course relied very heavily on hands-on experiences, field trips, and audio-visual materials. This emphasis was well received by both students and the outside evaluator (Prof. Steven Goldman, STS Program Director, Lehigh University). The proximity of the Great Falls and its raceway system and the timing of the hydroelectric redevelopment was truly providential. The Smithsonian and Edison laboratory sites were also essential to our goal of promoting the immediacy of technology studies. For many of our students, this was the first opportunity to really study (and even visit!) the city which shares the college's name. Students were particularly impressed with the electronic kits which provided the most meaningful experience in the study of electricity. The use of artifacts, from the Jersey Bar Fly (a metallic 'flag' used to signal the bartender when a customer wished to reorder), to Hero's Engine, to electric motors and generators, also well served the implementation of our goals of making technology tangible.

The team teaching framework was also well received. It is suggested that the dialogue among instructors was particularly important in stimulating discussion within the classrooom. Classroom discussions were frequent and and important to the learning climate. Perhaps the only immediate drawback to our team taught approach was that our course instructors were somewhat too agreeable and homogeneous in viewpoints, so that conflict, often an impetus for really pointed discussion, was lacking. (Students universally love to see professors argue.) Also, future course offerings will most certainly involve elimination of the true team teaching format in favor of either sequential multiple instructors or a single course instructor. Presently, administrative support of team teaching is minimal at this institution.

The use of films, videos, and audio-visual tapes was also critical to the appartent successes of the course. We began the course with the famous scene from *2001* where the proto-human throws his newly discovered club into the air and it turns into a rotating space station. The imagery of this scene provided a reference for the entire course. The Burke and Bronowski tapes also provided insight which no lecture could match. Finally, the Coppola film, *The Conversation,* provided an excellent counterpoint to the view of uncritical acceptance of technology. This remarkable film makes its point very directly. Unfortunately, time did not permit the showing of the film *The Right Stuff* with its very different view of technology.

According to the student evaluations, the three sections of the course were not well integrated and did not clearly address the stated objectives of the course. Despite the preponderance of science majors (80%) the quantitative aspects of the course, both in the electrical and assessment parts) were the poorest received. Attempts at making probability and electrical circuit calculations not only palatable, but even exciting, were obviously not highly successful. The area of quantitative skill development remains problematic, particularly when future offerings are expected to contain a majority of non-science students. The other significant problem was simply a lack of time. Despite several "overtime" sessions, it was clear that we did not cover the material as completely as anticipated. The assessment section suffered most because it went last. Part of this was due to additional time given to superconductivity, an extremely significant and topical technological development which was added to the curriculum mid-course. Expansion to a four credit course does not seem pragmatic for an elective course such as this. The lack of a textbook did not seem of particular concern according to the student evaluations.

Finally, two attempts to offer this course since the initial offering have failed due to lack of enrollment. We believe that this may, in part, be due to low student interest in water power. Consequently the course is now being reorganized with a different focus - telecommunications, again using Paterson as a case study, this time focusing on the city's unique TV cable system. A faculty member from communications has been added to the team for this offering. This course will be given as an elective in the Communication Department during the Spring 1988 semester.

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JAPANESE VALUES AND TECHNOLOGICAL DEVELOPMENT: A NEW COURSE

Heinz C. Luegenbiehl

Contemporary technological societies are beset by constant change. Often the value structures in these societies are out of harmony with perceived needs for further technological innovation. While it is recognized that technological development affects values and vice versa, in the United States the driving force in the equation seems to be the ever increasing demands of technology. This, in turn, means that often the underlying needs and values of the people affected by technological developments are neglected when decisions are made. A corrective to this neglect has been the recent emergence of studies in technology assessment and technology criticism. However, in general such studies have either narrowly focused on the assessment of existing proposals for the implementation of new technology or on a general critique of advanced technology. Yet it seems important that the study of values be utilized not only as a deterrent to proposed technological development, but also as a positive force in enhancing future technological capabilities. The course described in this paper, "Japanese Values and Technological Development," has that positive aim.

When the connection between values and technology is established, it is often done on the basis of a general understanding of impact analyses, where specific instances are cited only as procedural examples. I have found that my engineering and science students have difficulty thinking about the associated issues only in these general terms. For them, issues regarding the nature of technology, the environment, and social relations are distant from their immediate focus on the practical application of the skills learned in college. It is thus important, I believe, that ways be found to draw students into thinking about the broad, underlying humanistic issues entailed by any examination of technology in the contemporary world. Focusing on our foremost industrial competitor, Japan, can be a very effective means of beginning a dialogue regarding the effects of technological innovation on human life. Further, students are forced to become aware of the relevance of technology studies to their own lives when the subject is presented in the context of the Japanese success story.

Impetus for Development of the Course

Three years ago Rose-Hulman Institute of Technology instituted a program in East Asian Studies in recognition of the increased need for American engineering and science students to be able to understand, and to communicate with, their counterparts in Asia. Two Japan specialists, both anthropologists, were hired to serve as core faculty for the program. Since RHIT students major only in the sciences and in engineering, two additional positions reserved for the social sciences signified a substantial institutional commitment. However, it was recognized that in order for the program to be successfully integrated into the Institute, participation by other faculty members would be required to give the program sufficient breadth. This meant that current faculty in the Humanities and Social Science Division would have to gain some competence in Asian studies. On the basis of this need, the Lilly Endowment granted funds for course development and associated activities. We were thus able to bring to campus a number of nationally recognized experts in the field, attend meetings of Asian studies groups, and form an institutional study group. On the basis of our initial considerations we recognized that we would be unable give adequate coverage to all of Asia. The focus for the program thus became Japan, since that was where the core faculty could be of most help, with the eventual goal of integrating studies relating to other East Asian countries as well.

During the first year of the program an Orient Club was organized, a student study tour of Japan was undertaken, several surveys of student interests were conducted, and library resources in Japanese studies were enhanced thanks to a grant from the Japan Foundation. Our primary goal, however, was to enhance the curriculum. To that end, a proposed area minor curriculum was put developed and adopted by the faculty. The program, when completely established, will contain the following courses. Starred courses are already being taught. The Matsushita Foundation is currently underwriting the development of several additional courses.

*Japanese Language I, II, III
Japanese Language and Introduction to Technical Translation IV, V, VI
*Introduction to East Asia (Anthropology)
*Japanese Society (Anthropology)
*Japanese Values and Technological Development (Philosophy)
*Japanese-American Relations in the Twentieth Century (History)
*Economic Development of Contemporary Japan (Economics)
*Comparative Management Strategies
Contemporary Issues in Japanese Society (Anthropology)

Japanese Politics and Public Policy (Political Science)
Japanese Philosophy and Religion (Philosophy)
Japanese Literature and Film (Literature)
The Orient Through Occidental Eyes (Literature)

When completed, we hope that the program will serve as a model for undergraduate international education in science and engineering. Our research to date has unfortunately shown that very few such programs exist, and those that do are generally directed at graduate students.

The Course

In planning to teach a course in the program, I drew on my own background as much as possible. I have, for a number of years, taught courses in Oriental Philosophy and in Technology and Human Values. I gained additional background through an NEH Summer Institute on comparative philosophy at the University of Hawaii and through research trips to Japan and the University of California at Berkeley. I then devoted an entire summer to research and to becoming acquainted with the literature on Japanese society and Japanese technological innovation. While I found that most of the more philosophical connections between values and technology in the Japanese context had to be established by me, there is sufficient social science literature available to serve as a solid basis for the course.

The aim of the course is to discover whether rapid technological development can be compatible with a set of traditional values, and to draw comparative lessons from the results of the study. Japan is a society where traditional values are much more firmly embedded than in the U.S. The first phase of the course focuses on the values which govern Japanese society and enunciates the relevant underlying conception of the human being. The students are introduced to the nature of values and study the religious basis of current Japanese social values. The course then focuses on the historical evolution of current social values and compares these to the dominant values in the United States.

In its second phase, the course focuses on major characteristics responsible for the success of Japanese technological innovation. The class first gains an understanding of the nature of technology and of the various attitudes which are held toward technology in general. General criteria for the assessment of technological developments can thus be introduced. The focus is then placed on the study of technological innovation in the Japanese context, with emphasis on the evolution of electronics and computer technology. In this part of the course a study of Japanese corporate culture and its relationship to innovation is also undertaken.

The final part of the course considers the relationship of Japanese values to success in the international marketplace. Japan is compared to the United States on the basis of competing social models; one where the group is given primary emphasis and the other where the individual is seen as having priority. The students are finally asked to see what lessons, both positive and negative, can be learned from the Japanese experience and to consider the difficulties associated with transferring particular value emphases from one society to another.

A significant portion of the time the students are expected to devote to the course is given to the development of a term project, which occurs in four phases. While the course as a whole deals with technology and values in a general way, in their projects the students are expected to focus on a particular interaction of the two. The first phase of the project involves researching and writing on a particular Japanese value. The second phase does the same for a particular Japanese technological innovation. It is made clear to the students that innovation involves the process of bringing a product to market, so that they are not required to deal with a technology that was invented in Japan. The third phase consists of writing a thought paper on how their two previous studies are related, to connect their study to the general relationship of technology and values established in the course, and to draw lessons from their study. Each student is then required to present the essence of the results in a short oral presentation to the class.

Course Assignments

The major texts for the course are Michio Morishima, Why Has Japan 'Succeeded'? Western Technology and the Japanese Ethos (Cambridge University Press: 1982) and Masanori Moritani, Japanese Technology: Getting the Best for the Least (Simul Press: 1982). Although Morishima is an economist, his main emphasis in this book is on the historical evolution of Japanese values. He emphasizes the significant changes in Japanese culture due to the Taika reform (6th century) and the Meiji Restoration (19th century). The book is good for a humanities oriented approach to the subject, due to its emphasis on understanding the religious sources of current Japanese society and its historical analysis of Japanese social structures. Moritani's book has a two-fold emphasis, on the specifics of Japanese technological innovation in the post World War II years and on the main themes of corporate culture in Japan. It deals extensively with developments in electronics and computers. Noteworthy about Moritani's approach to "comparative technology" is his demonstration that both Japan and the West have things to learn from the other's cultural characteristics in the domain of technological innovation.

In addition to the two main texts, the course also requires supplementary reading from other sources. These range from basic conceptual analyses in Kurt Baier and

Nicholas Rescher, editors, Values and the Future (The Free Press: 1969) and Albert H. Teich, editor, Technology and the Future (St. Martin's Press: 1986) to popular accounts from Time, Newsweek, and Business Week. (A complete syllabus and lesson description is available from the author on request.) The emphasis throughout the course is on in-class integration of materials from a variety of sources based on background lectures and class discussion. On the basis of the readings, the students are asked not only to think about fundamental value structures, but also about how these apply in relation to specific instances of innovation.

The diversity of possible topics appropriate for consideration in the course is illustrated by some of the projects topics developed by the students. In the first iteration of the course these included Paternalism and VLSI Development, Groupism and Japanese Architecture, Harmony and the Sony Trinitron Television, Nationalism and the Oval Piston Racing Engine, The Family and Robotics, Education and Artificial Intelligence, and Loyalty and the Japanese Automobile Industry.

Lessons Learned

Courses such as the one described in this paper, which have both the aim of increasing the humanistic understanding of students and of dealing with a topical and controversial issue, have the potential to reveal new or previously implicit lessons to the teacher of technology studies. The convergence of the general and the specific in one discussion permits reflection on the purpose of such studies. By way of conclusion, I will point out some of the insights I gained, proceeding from the more abstract to the quite context specific.

1. The well-known feedback loop is useful for analyzing technological development in both the Japanese and the Western context. However, by dealing with specific applications of the loop it becomes apparent that the usual form of examination consists of beginning with an invention and tracing out its value consequences. When two different cultures are compared, on the other hand, the true importance of values as the source of technological innovation comes to the fore.

2. In dealing with technological change, a hidden premise of many discussions appears to be that modern technology can be examined independently of underlying cultural contexts, that the primary distinction is between technologically advanced and technologically underdeveloped countries. It should, however, also be recognized that the notion of "a technological society" embeds numerous possible divergent interpretations within it.

3. When dealing with transfers between societies within the context of technology and values, the focus is most often placed on the transfer of technologies and

difficulties encountered in the acceptance of technologies within a different value context. Since the primary emphasis in this course is on the development of new technology, however, the focus has to be on value transfer from one societal context to another. This brings to the fore the troublesome personal question of how deeply attached we are as individuals to an existing value system and the more theoretical issue of what systematic implications a change of emphasis on a particular value will have in a particular social context.

4. Comparison of the West to Japan, because of their different social structures, shows that the examination of technological development must be based on an explicit model of society, it cannot just be based on characteristics of technology itself.

5. Emphasis on lessons to be learned from the Japanese experience permits focus on specific technologies, but on a non-arbitrary basis, since specific values are associated with specific forms of technological innovation.

6. Focus on the Japanese context helps to clarify the distinction between invention and innovation, since much of Japanese technological progress is based on the further development of existing technologies. This also shows the importance of corporate norms and expectations in the process of technological adaptation.

7. Students often have difficulty separating science and technology, especially since in our culture the two are frequently explicitly intertwined. The historical rejection of basic science in Japan conjoined with Japan's technological success forces students to rethink their assumptions about the nature of science.

8. Studies of technologies and values often turn into an examination of how technological development should be restricted so as not to destroy "traditional" values. This course permits an emphasis on the positive, by focusing on how an emphasis on certain values can aid technological development. A deemphasis of the common "is technology good or evil" issue is a natural consequence.

It should be noted that a real danger associated with utilizing Japan as a basis for comparison is its potential for putting students on the defensive. They exhibit some tendency to see either only the positive forces for technological development that exist in Japan and which might be missing in the United States or they reject out-of-hand the communitarian vision which is central to the success of Japan. If this restricted perspective can be overcome, however, then examination of Japan and the United States can achieve a deeper purpose common to all technology and society courses: to reflect on what technologies are for, to think about the pace and direction of technological change, and to consider what we want the future to look like and what the role of the individual should be in the creation of that future.

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INTEGRATING THE TWO LITERACIES:
HUMANITIES IN THE ENGINEERING CURRICULUM

Barbara M. Olds and Ronald L. Miller

Introduction

We hear a great deal of justifiable concern these days about the "technological illiteracy" of our society. C. P. Snow's "two cultures," the technological and the humane, seem to be increasingly separated, the lines of communication between them nearly nonexistent. Even when we attempt to break down the barriers between the two cultures, we often move in only one direction, increasing the technological literacy of the liberal arts community. In many colleges and universities, curricula are being devised to ensure that we are graduating liberal arts majors with at least a rudimentary understanding of science, technology, and society.

However, in our rush to inform liberal arts students about technology, we sometimes neglect or denigrate the necessity of "bi-literacy" for students of science and engineering. As faculty members in an engineering school, we are particularly aware of this problem. Granted, every engineering student must take a certain number of courses in humanities and social sciences mandated by ABET, the Accrediting Board for Engineering and Technology. Some engineering schools have made excellent use of those hours; some have even increased the humanities requirements at their institutions dramatically. However, our experience shows that required humanities hours are often 1) not taken seriously by the student who is eager to get on with the "important stuff" of engineering and, 2) not related in any obvious way to the student's professional goals. As a result, much liberal education for engineers simply becomes a second set of unrelated courses completed in parallel with the technical course requirements.

We believe that in order to promote a healthy balance in our society, to avoid a further rift between the "two cultures," we need to educate future scientists and engineers in several essential areas:

- Communication skills
- Open-ended problem-solving
- Cultural background and contexts

We see such education working best when it takes place in an integrated curriculum in which faculty from liberal arts disciplines work alongside faculty from science and engineering departments to educate the whole student. We have several initiatives underway at the Colorado School of Mines (CSM) and are developing others which we believe will further this process.

Certainly, anyone who has read a newspaper in the past year has been confronted with the barrage of arguments in favor of an increased emphasis on the liberal arts in American higher education. Allan Bloom's The Closing of the American Mind (1987), E. D. Hirsch, Jr.'s Cultural Literacy (1986), and Lynne Cheney's American Memory (1987) have all been widely discussed both on college campuses and in the popular press. Their basic argument, that we need to know something of our culture in order to fully participate in it, is widely accepted even if some of their suggestions for implementation are roundly disputed.

Engineering educators are also becoming increasingly aware of the need to increase the breadth of their students' education. The December 1987 issue of Engineering Education, for example, devotes several articles and its cover to a discussion of the relationship between engineering and the humanities. In a provocative short excerpt from his book, The Civilized Engineer, Samuel C. Florman defends the general "honesty, conscience, and good citizenship" of engineers and repeats their impatient retort to those who would increase the liberal arts component of their education that, after all, "in a technological age it is the technologically uninformed who are the true know-nothings" (162).

Florman continues, however, that he is "nevertheless convinced that the quality of our technology, and consequently the quality of our lives, would be improved by the liberal enrichment of engineering education, by the broadening of horizons, the deepening of cultural awareness--in short by the civilizing [our emphasis]--of engineers" (162).

The Colorado School of Mines has adopted a goals statement that also emphasizes not only the need for a strong technical education for our students, but also "the critical need for students to develop their communication skills, to appreciate their cultural heritage, to understand the social, economic, and political environment in which they work, and to achieve intellectual growth through life-long learning" (CSM Strategic Plan, 3).

It is within this educational context that our integrated programs are set. We will discuss our interdisciplinary efforts and plans in the areas outlined above: communication skills, problem-solving skills, and cultural knowledge.

Communication Skills

We believe that engineers must be able to communicate effectively to a variety of audiences, including nontechnical ones. We do not believe that they can ultimately rely on others to disseminate important information in an understandable form. For this reason, we strongly stress communication skills in our two-year required EPICS (Engineering Practices Introductory Course Sequence) course. Nor do we define "communication" narrowly: we include not only written and oral proficiency, but also graphic and computer literacy in our course, since all of these skills are necessary for the contemporary communicator. Over four semesters of instruction our students learn and then practice many times:

- Written Communication
    - Audience Analysis
    - Keyword Analysis
    - Document Design
    - Report Writing
    - Editing for Readability
    - Memo and Letter Writing
    - Meeting Minutes
    - Progress Reports
    - Integration of Effective Visual Aids
- Oral Communication (Staff Meeting Format)
    - Progress Reports
    - Informational Reports (Expert & Non-expert Audiences)
    - Cross-examinations
    - Persuasive Reports (to Outside Clients)
    - Use of Effective Presentation Aids (Flip Charts, Overheads, Slides, etc.)
- Graphics
    - Free-hand Drawing
    - Engineering Drafting
    - Computer-aided Design
    - Software Packages
- Computing
    - Two Languages (BASIC, Fortran)
    - Three Computers: programmable calculator, personal computer, mainframe
    - Problem-solving Techniques

Through practice over their four semesters in EPICS, students generally become proficient in these areas. However, our current efforts are aimed at assuring that they have opportunities to continue to practice and refine their skills. We are now developing new programs that will: 1) integrate instruction on these skills into the junior-level summer field sessions which all of our students are required to attend and, 2) integrate communication instruction into the required capstone senior design experience. Both are logical extensions because students in these courses are currently asked to use their communication skills in writing extensive reports and making frequent oral presentations. Our concern is that they need continued instruction in these areas, not just practice. Therefore, we will be working with engineering faculty to develop effective methods of instruction in these courses.

Problem Solving

Problem-solving skills are another area where engineers must excell. Unfortunately, engineering students are too often taught that any problem can be solved using the "3-cubed" approach (three lectures a week, three problems a night, three hour exams, and a final). Such an approach "is efficient at presenting information on a content-based subject such as differential equations or physical chemistry" and it is supported by most textbooks with the answer-at-the-back-of-the-book format. However, "it does not effectively model the way engineers approach real problems, starting with problem definition" (Pavelich, et al., 280). Nor does it take into account the types of real life problems engineers must solve, problems for which there is very often no one "right" answer and which include a number of constraints (legal, ethical, cultural, political, environmental, etc.) which must be factored into a solution.

We introduce our freshman and sophomore students to open-ended problem-solving using a decision process developed by Charles Wales at the University of Virginia. In their first semester, students learn the decision process by working in teams on a case study. They systematically solve a problem by applying Wales' steps. While we go through the process sequentially with the case study, we make it clear to the students that experienced decision makers don't necessarily follow the process lock-step. In fact, we often reverse the solution and constraint generating steps in our classes. We do emphasize, however, that some sort of systematic approach to problem-solving is important.

During the remainder of their first two years, students have several opportunities to practice this decision-making process by solving a series of increasingly complex open-ended problems. These "real world" problems, provided by clients in industry, government, and academia, include technical elements, certainly, but they also contain numerous non-technical constraints of the types outlined above. Our students become very proficient at this type of problem-solving.

We have some concerns, however, about the carry-over effect of these abilities. For this reason, we are reexamining summer field session and design classes to make sure that the gains our students make in their first two years aren't lost by their senior year. Since we strongly believe in the value of experiential learning, we want to ensure that their field session and design projects challenge our students in the same open-ended ways as the earlier problems. We also want the students to see in increasingly sophisticated ways the means by which a knowledge and understanding of humanities can be important to them professionally as well as personally.

Humanities Education

We believe with Alfred North Whitehead that "the antithesis between a technical and a liberal education is fallacious. There can be no adequate technical education which is not liberal, and no liberal education which is not technical; that is, no education which does not impart both technique and intellectual vision."

This final area of integration is perhaps the most difficult to achieve, at least on the surface. Engineers are generally willing to concede the need for communication skills and for problem-solving ability and to accept gladly whatever help the liberal arts faculty can supply in these areas. However, when the role of humanities in the curriculum comes up, the arguments Florman summarizes are likely to be mustered quickly: "I have met hundreds of engineers and engineering students who for all their unfamiliarity with literature, history, and the arts, are good, productive, responsible members of the community. Small wonder that so many engineers and engineering educators resent being derided for lack of 'culture' and resist attempts to increase either the length of the engineering college course or its liberal arts component. The system works as it is, they maintain, and who can gainsay them?" (162).

In addition, academic politics may be an issue for, as Florman points out, "long-standing prejudices and academic politics make change difficult and interdisciplinary cooperation a low priority" (163). On large campuses, liberal arts faculty are ensconced in their own departments and have little motivation, personally or academically, to teach engineering students. At smaller engineering schools like CSM the liberal arts faculty work specifically with the engineering students, but their departments are often "viewed as second-class citizens, and their offerings are thus tainted" (163).

Though we have faced some resistance to our integration efforts, overall the CSM faculty and administration have supported our work. As a result, with the help of a grant from the National Endowment for the Humanities, we are planning a new course which we will offer next year for the first time which will truly integrate humanities into an introductory chemical engineering course. We see this effort as a pilot with implications for many other courses on our campus and at other institutions.

We decided to try to integrate humanities into engineering courses because of what we hear from our students and what we remember from our own undergraduate education--it is extremely difficult to see the connections between what seem to be completely unrelated disciplines and course content. Too often we ask engineering students to take a certain number of hours in humanities, assuming that they will see the relevance of what they study to their chosen profession. In a majority of cases, the connections simply aren't made and we graduate another generation of engineers who see their humanities background as at best "frosting" and at worst a waste of time.

Our objective is to develop an integrated humanities/ engineering course to be offered within the existing chemical engineering curriculum at CSM. This course, a model for other courses in other engineering departments, will help to educate engineering students to understand the cultural and social constraints on their technical work. All

CSM students are exposed to such ideas in their freshman year through our flagship Crossroads course, an interdisciplinary introduction to humanities and social science. Our new course will build on this background in a sophomore junior-level chemical engineering course, CR 301, Introduction to Chemical Process Principles. The current course focuses almost entirely on teaching students quantitative calculations for analyzing chemical processes. The new course which we are developing will supplement and complement existing technical course material with selections from literature, philosophy, ethics, and history.

In our course we will introduce students not just to "number crunching" (the current approach), but to broad questions of great importance to them as future professionals. Among these questions:

1) Where do our concepts of science and engineering come from and how valid are they?

2) What non-technical constraints should concern me as an engineer: ethics, personal honor and integrity, power over the environment and other people? How do I make decisions about these complex issues? What great minds have asked these questions before, and how have they answered them?

Over the course of the semester, while we are studying chemical processes we will also be studying the myth of Prometheus, excerpts from Plato's Republic and Aristotle's Ethics, Marlowe's Doctor Faustus and Shakespeare's The Tempest. All of these sources raise questions about personal ethics, power, and the danger inherent in misuse of knowledge.

The course will be team-taught by a humanist and an engineer, each an expert in his/her own area, each knowledgeable in the other's. We are currently working to develop truly integrated lectures, readings, discussion materials, case studies, essay topics, and homework assignments. In addition, we are substantially changing the course format, including:

- Emphasizing class discussion rather than lecture.
- Writing about the readings and their application to the students' personal and professional lives.
- Drawing connections between the technical and non-technical aspects of the course.

We are extremely excited about the potential for this course and the implications it carries for the education of scientists and engineers. We agree with Samuel Florman's contention that "liberal education, by expanding the intellect and exercising the imagination, can make engineers technically more able," not only in the important areas of written and oral communication, but also "in the non-verbal creative recesses of the engineer's mind," where "flexibility and variety--poetry, art, music, stories, myths--have a constructive role to play" (163). We want to see a coherent, integrated curriculum like the one outlined in Figure 1. Through such courses as the ones described here, we hope to educate engineers who possess the breadth which the liberal arts provide and who are thus able to make good decisions in a complex society which requires them to be "bi-literate," capable of using their skills in both technology and humanities.

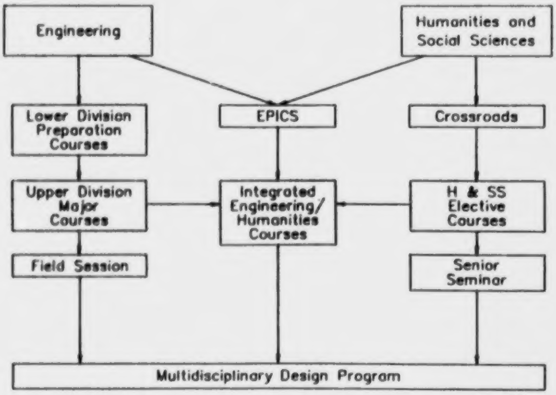
Engineering
Humanities and Social Sciences
Lower Division Preparation Courses
EPICS
Crossroads
Upper Division Major Courses
Integrated Engineering/ Humanities Courses
H & SS Elective Courses
Field Session
Senior Seminar
Multidisciplinary Design Program

Figure 1. Integration of Humanities Education into the Engineering Curricula at CSM

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MATHEMATICS-ACROSS-THE-CURRICULUM: A MODEL PROJECT FOR THE APPLICATION OF QUANTITATIVE REASONING ACROSS THE CURRICULUM

Patricia K. Monoson, Ann Elder and Julie Gowen

It is becoming more important for individuals to acquire quantitative reasoning skills in order to function adequately in our increasingly technological society. Evidence of the social value placed on such skill is demonstrated by the suffusion of mathematics courses throughout the educational experience from kindergarten through high school.

This apparent emphasis on mathematics education has not resulted in adequate mathematics competence of current elementary and secondary students. Current education reform efforts stress the need to require more mathematics coursework of students for high school graduation. The Carnegie report (Carnegie Forum on Education and the Economy , X, 1986) stresses the need to improve students' understanding of quantitative concepts along with improving other practical skills.

Lack of quantitative reasoning skill is evident from the ACT entrance test scores of college freshmen reported nationally. Table 1 summarizes the ACT results for high school graduates and for freshmen entering Illinois State University for the last seven years. The mathematics subtest scores are, on an average, lower than any of the other subtest scores. The average mathematics subtest score at Illinois State University was about 19; however, the scores ranged from 1 to 35 - the whole range of possible scores on the test. Obviously, something is lacking in the educational process when a substantial number of students cannot perform above a chance level (25 percent) on standardized achievement tests for quantitative reasoning ability.

In order to improve and reinforce mathematics ability in college students, one of the strategies adopted by many colleges and universities is to require a college level mathematics course. Typically, students see no value in acquiring more mathematics skill and view the course only as another hurdle to graduation. As a consequence, such courses seldom achieve their goal of improving the mathematics competence of students or their usage of quantitative reasoning.

One way to counteract negative student attitudes about mathematics is to integrate mathematics with course material in traditionally non-mathematics disciplines. This approach has several advantages. One is to provide a practical application for abstract mathematics concepts. A second advantage is to provide an illustration of the utility of mathematics. Finally, integration of mathematics and disciplinary content allows students to utilize mathematics as an alternate language for understanding abstract disciplinary concepts.

One strategy to promote transition of mathematics reasoning to disciplinary courses is COMAP (Umap Modules, 1982). This published material is designed to

Table 1
National and Local Norms for the ACT

ENROLLED COLLEGE STUDENTS - FRESHMEN
NATIONAL - 10% SAMPLE

	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88
English	18.1	18.0	18.2	18.1	18.4	18.6	18.9	
Math	17.6	17.3	17.4	17.3	17.6	17.8	17.7	
Social Science	17.5	17.6	17.8	17.7	17.7	17.9	18.2	
Natural Sci	21.3	21.3	21.2	21.1	21.3	21.6	21.7	
Composite	18.7	18.7	18.8	18.7	18.9	19.1	19.2	

ISU (LOCAL) - LOCALLY GENERATED NORMS

English	19.15	19.23	19.59	19.33	19.53	19.65	19.91	20.01
Math	19.24	19.19	19.78	19.39	19.34	9.57	19.59	19.78
Social Science	18.82	19.01	19.39	19.44	18.77	19.38	19.30	19.30
Natural Sci	22.14	22.12	22.32	21.97	22.01	22.62	22.56	22.65
Composite	20.13	20.17	20.60	20.16	20.05	20.42	20.47	20.59

bring discipline subject matter into the mathematics courses. Unfortunately, most of this new curricular material is designed for mathematics courses at the level of calculus or above where students in the humanities and social sciences are seldom enrolled.

An alternative approach utilized at Illinois State University has been to incorporate quantitative curricular materials into courses that traditionally have little mathematics in the course content. In order to suffuse quantitative reasoning into courses in the humanities and social sciences, three essential elements had to be addressed: the development of a committed faculty, new course material, and receptive students. Since 1985, a program has evolved that concentrates on quantitative curriculum development by attending to these three elements.

This approach is designed to promote improved mathematics attitudes and to maintain quantitative skills and is appropriate for many institutions. Illinois State University is a typical comprehensive university with an undergraduate student enrollment of over 20,000. Student ACT scores are average for incoming freshmen. Among our students, the mathematics subtest average was the second lowest average but had the widest range of all subtest scores. One quarter (971) of the entering freshmen at I.S. U. fell below the national average of 17. There was and is a need to help students further their development of quantitative reasoning ability and learn to apply these skills in the appropriate situations.

A pilot program to meet these needs was first developed at Illinois State University in 1985. After initial testing confirmed our expectation that Arts and Sciences majors in departments other than mathematics and the sciences lacked strong quantitative skills, a program was developed to achieve an integration of quantitative material in general studies courses which initially had little quantitative content. This approach was chosen for several reasons. First, the inclusion of mathematics in a large number of University studies courses gives students fewer places to hide from the need to be proficient in mathematics. Second, the use of mathematics in other courses should reinforce the mathematics training students receive. Third, the application of matnematics skills in courses such as history, political science, or English should underline the relevance of mathematics to a wide variety of disciplines. Finally, successful application of mathematics skills to problems in these disciplines should bolster student confidence and lead to more positive approaches to solving problems using quantitative reasoning.

In this first summer, faculty from four departments were invited to develop curricular materials that incorporated quantitative reasoning content into their general education courses. The faculty participated in a seminar to discuss the development of these materials. After preparation of teaching modules applying mathematics to problems or projects appropriate to their disciplines, the participating faculty members then utilized these modules in their general education courses during the school year.

Mathematics achievement levels and attitudes toward mathematics were assessed for students in these courses at the beginning of the course and at the end. The test of mathematics competency again examined students' mastery of the skills in Table 2. The other examination measured student attitudes toward quantitative reasoning. The earliest pilot data on a limited number of college students indicated that although their mathematics skills did not change significantly in one semester (an exception to this was in a Thinking Logically course given to adult learners), their attitudes towards mathematics improved when compared to their attitude at the start of the semester (Gowen and Owen, 1986).

Because of the encouraging results from the first experience, a second summer faculty development seminar was conducted in the summer of 1986. A faculty member from each of the 15 college departments except mathematics participated in that seminar. The seminars were held over a three week period of time. The first day of the seminar, the faculty participated in a general discussion about mathematics skills and the relationship of these and their content area. They were exposed to the notion that mathematics is a language similar to visual and verbal subdivisions of language.

Table 2
Mathematics Competency Examination Areas

Elementary:	Basic Four operations with whole numbers, rational numbers and decimals Basic proportions and their solutions One-step application problems Organization of data into a list and examination for simple patterns
Intermediate:	Operations extended to working with radicals, exponents, and roots Advanced proportional reasoning and use of proportions in applied settings Two step application problems Use of descriptive statistics involving measures of central tendency and variation Interpretation of graphical information in line, bar, circle, or other forms Elementary algebraic skills and concepts
Advanced:	Operator involving polynomials and functions and their interpretations in graphic form Probabilistic concepts and skills through joint events and conditional settings Situational problem solving involving problem solving strategies and their applications Statistical distributions and their characteristics along with samples and their characteristics Construction of tables and graphs to make an argument Algebra of sequences and series, logarithms, and nonlinear functions

Faculty were introduced to sample modules that had been developed by the four faculty members who had participated in the previous years seminar. The second workshop was held one week later at which faculty were encouraged to talk about their ideas for suffusion of mathematics within their discipline and specifically within their courses. At the end of the session, faculty were asked to take these ideas and develop two or three teaching modules that incorporated mathematics material into their current course content. The last meeting during the third week of the workshop was devoted to dealing with mathematics anxiety both in the students they would instruct and their own lingering anxiety about mathematics. The modules were turned in by faculty at the end of July, reviewed by the committee overseeing this project and returned to faculty with comments before the fall semester began.

A vital part of this second year project was the evaluation of its effectiveness. Students' mathematics achievement and attitudes were assessed at the beginning and end of the semester. The test of mathematics competency continued to examine the three basic areas identified in Table 2, but the questions on the third version were compiled from various standardized mathematical achievement tests available on the market. In order to ensure that the outcome of tests of student performance was not attributable to some uncontrolled variable, similar groups of general education classes that were not exposed to new mathematics materials within their courses were used as a control and given the same tests at the beginning and end of the semester. Students were given two randomized versions of these tests.

A second test was administered to students to assess their attitudes towards mathematics. The attitude test was constructed by consultants familiar with this form of assessment. Questions ranged from statements such as, "Math is essential for career success," to "I get nervous when I have to do math." It was also administered at the beginning and end of the semester.

Approximately four thousand students were assessed on the pre-and post-test achievement and attitude tests. Half of those students were exposed to the new quantitative teaching materials and were designated the experimental group. Out of the 4000 students who were identified for testing, only 719 students completed all components and were included in the analysis. Five hundred and forty-one were in the experimental group and one hundred and seventy-eight were in the control group.

The data collected from these tests were subjected to ANOVAs in order to determine the extend to which the experimental treatment, suffusion of quantitative curricular material, improved students' mathematics ability and changed their attitudes towards mathematics. Gain scores were computed using the scores obtained on the initial testing and the testing at the end of the semester. No significant difference was found in student achievement between the group exposed to mathematics material and the group that did not have added mathematics material. in fact, neither gender nor overall achievement as measured by the composite ACT test scores were associated with differences in mathematics achievement between the experimental and control groups. The only variable which was related to differences in performance on the pre- and post-achievement test was the performance on the initial pre-test mathematics achievement test. Those students who fell below the mean score (14.6) were grouped into a category labeled low achievers. Students in the high achievers group gained significantly more than did students in the low group. This means that students who began with better mathematics skills were better able to improve these skills with the additional practice and application of mathematics concepts they received in general education courses. Those with poorer skills may have been less motivated to try to improve their skills or they may have avoided doing the mathematics-oriented class projects that might have helped them to improve. In any case, it seems unlikely that a single semester's exposure to mathematics-enriched curriculum in general education courses will significantly aid the group most in need of the help.

With regard to the test of attitudes toward quantitative reasoning, both groups - experimental and control - improved. Although students did not necessarily improve their quantitative reasoning ability in one semester, there was clearly a change in their attitude toward mathematics. In addition, the group of high achievers also showed a stronger improvement of their attitude toward mathematics, perhaps illustrating the effect of aptitude on attitude. This is revealing because it may also point to the negative reinforcement between poor mathematics skills and a poor attitude toward math. Students who do not do well initially may be less motivated than more gifted students to make the effort to improve their quantitative reasoning skills.[1]

Based on these test results from the second year of the project, modifications in the faculty development workshops for the third summer were made. Experienced teachers were selected for the faculty development program, and close contact was maintained with the participants throughout the semester in which the new material was employed. As before, faculty were paid a stipend for their participation in the program. Five departments were invited to send a team of two participants to the curriculum development workshops which were similar to the those of the previous summer. By having two participants from each department, those from the same discipline were able to share their problems and perspectives, to provide each other with support and feedback, and to constitute a core of persons within the department to help other interested faculty within their field to utilize the modules that were developed. The faculty participants in the project were selected on the basis of their stated interest in the project and their assignment to teach general studies courses. There was no attempt to choose faculty who taught only small classes. Rather, the faculty participants included individuals who taught classes ranging from 18 to more than 300 students. Undergraduate Teaching Assistants (UTAs) were provided to those faculty who requested help so that grading student assignments would be less onerous.

The summer workshops were staged on three days, spread over a period of two weeks. These workshops were staffed with two master teachers who were previously successful project participants, two mathematics consultants, and the project coordinator. Participants were given an outline to guide their development of the teaching modules and were asked to develop one teaching module and plans for the development of two more during the next month. Some workshop time was used to provide participants feedback from both successful teachers and mathematics consultants on the one module they developed. Nine of the ten participants completed the workshops and used the modules in their general education classes.

At the end of the semester that the modules were used, the participating faculty completed a questionnaire about the usefulness of the workshop, the materials, and the student performance. By and large, the faculty had a positive response to the suffusion of quantitative reasoning material into their courses. Several participants were pleasantly surprised at the positive response from their students. One English faculty member who was initially highly skeptical about the appropriateness of this curriculum approach for his course on the Bible as Literature eventually developed a method of quantifying stylistic differences among various versions of the New Testament. He became so enthusiastic about his approach that he changed the focus of his whole course to accommodate his new material. A sample of his module is found in Appendix 1.

Beginning with the summer of 1988, the faculty workshops will continue with some modification based on feedback from the 1987 participants. The expectation of improvement in mathematics skill from a single semester's exposure to the new curriculum within a discipline has been altered. Rather, assessment will involve change in mathematics performance after completion of the 48 hours of general studies requirements. Further, more emphasis will be placed on student learning strategies. During the summer and fall of 1988, five departments from the social sciences and humanities will be chosen to send five to seven representatives to participate in the development workshops. An outside expert from each discipline will be invited to conduct part of the workshop, particularly to address the strategies for development of quantitative reasoning material. More emphasis will be placed on developing teaching materials that have student/faculty interaction; and more emphasis will be placed on student cognitive development. These two areas are targeted for increased attention because faculty have not necessarily been exposed to these areas in their own education. Assessment of the success of the model program will be based on both observation of the classroom experience and formal testing similar to the previous years' evaluation tool including some assessment of students' cognitive level of achievement.

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[1] A more detailed statistical analysis was computed with the data and is available upon request from the authors.

The outcomes from these workshops are multiple. Students should have an added tool to use to understand and analyze their discipline content. They should also be equipped to better deal with our increasingly technological society. Faculty members will have new interactive teaching materials that should facilitate student learning. Finally, mathematics faculty should have a better idea of what mathematics skills students will need and perhaps develop some interest in developing "curriculum across the math".[2]

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[2] The authors would like to thank John Leadley of the Economics Department, Illinois State University, for his assistance in the statistical analysis.

Appendix One

English Teaching - Shields
Math Across the Curriculum Module:
Analytical Identification of Style - 2 Exercises

English 251

The Apocrypha and New Testament as Literature
Fall, 1987

Topic: Measuring and Distinguishing Characteristics of Style Among the Synoptic Gospels in the King James Bible.

Objectives:

1) To determine whether style can be described in quantitative terms
2) If so, then to discover how best to set up such quantitative means or instruments
3) To test this empirical data against the traditional, a priori approaches to descriptions of style
4) To grasp the limits of this quantified approach and hence
5) To discover that a quantitative approach is most effective only when attended by a priori methods derived from considerations of taste and judgment
6) And finally to arrive at a more thorough and defined grasp of precisely what is style.

Mathematical Concepts Applied:

1) percentages
2) proportions
3) addition, subtraction, multiplication and division
4) graphing
5) analysis of statistical relationships--interpreting organized data

Synopsis of Project: We are all acquainted with the notion of judging style (the way an author expresses him or herself) on the bases of such a priori criteria as clarity, simplicity, turgidity, complexity, "essential gaudiness" (a la Wallace Stevens), floridity, grandiloquence, sesquipedalian ponderousness, felicitous or infelicitous diction, etc. While making such judgments, however, we seldom take into account, at least in any methodical manner, empirical data which probably do contribute on an unconscious level to our drawing of particular conclusions. The objective here, then, is to enable students to draw conclusions which describe style, not simply by the application of a priori criteria, but first by charting and/or graphing data accumulated through finite detailing of stylistic peculiarities (a posteriori) and second by discovering whether such quantification of stylistic peculiarities yields substantive means toward describing individual or characteristic style.

Since the text for this course is the King James Bible, we are confronted at the outset by the problem of the necessary tendentiousness of a translated text. As we will be working for the most part with the synoptic gospels (Matthew, Mark and Luke), however, the greatest portion of any anxiety caused by working with a translated text (subjected by the way to several removals from anything even remotely resembling an original intention) should be allayed. It should be understood that this project's objective is--not merely to arrive at criteria for judging whether one style is better or worse than another--rather to derive the means to identify sufficient characteristics of one body of writing so as to distinguish it from another. In other words, after we have accumulated our data and determined its descriptive applications, we will then pursue such questions as why is one style simpler or more complex than another? why does one gospel employ more active verbs while another uses more passive verbs or more "to be" verbs (hence less visual or dramatic)? do these stylistic characteristics suggest an audience? or a particular message? or what?

Analytical Identification of Style
Preliminary In-Class Exercise I

A central objective in any literature class is to enable students to become better readers, one means toward achieving the objective of becoming better readers is to acquire the capacity to identify style--to isolate particular traits or characteristics which distinguish one author's manner of expression from another. Since we are working with a text which is most definitely the product of many hands and that product a translation, we can not profitably hope always to be able to distinguish one author's style from another. We can, nevertheless, describe how one text differs from another, and perhaps we can even suggest why one text differs from another (i.e. suggest why one text expresses itself in a peculiar manner and perhaps even offer an interpretation regarding to whom that text addresses itself).

Today computer technology has made it possible for professional readers of literature to amass large bodies of data which describe, for example, how often a particular author uses passive verbs in proportion to how ofte he or she uses active verbs or how frequently he or she selects adjectives (modifiers or qualifiers) in comparison to how often another writer practices the art of qualifying or describing. Hence once and for all, it has been determined that Francis Bacon could not have written Shakespeare's plays! Even though we will not have the benefit of computers, neither will we examine large portions of a particular text (whew!). We will, however, now compare small, parallel portions of two texts, attempt to detail or to record their peculiar traits or characteristics and subsequently draw calculated conclusions about their styles.

Below on the left is a short passage from Tyndale's Pentateuch; on the right is a parallel passage from the King James Version. After you have recovered from the shock of Tyndale's archaic spellings (in this case, not to be considered as a stylistic difference), try to describe such characteristics as types of sentence structure, choices of words, kinds of phrasing, and patterns of rhythm. Then, using the data you've obtained (here it would probably be most simple and fastest to make small tables), draw up an overall description of each passage first and second attempt to make a comparative description of both passages, perhaps determining which one reads better (more smoothly, dramatically or forcefully) and of course explaining why, in detail, you have drawn these conclusions. No grade on this one!

Tyndale	KJV
"For behold I will bringe in	"And behold, I, even I,
a floud of water apon the	do bring a flood of
erth to destroy all flesh	waters upon the earth,
to	
from under heaven, wherin	destroy all flesh,
breth of life is so that	wherein is the breath
all that is in the earth	of life, from under
shall perish."	heaven; and every
	thing that is in the
	earth shall die."

Procedure for Evaluation: Since this exercise requires a detailed, written analysis of the data accumulated, it will function well as an out-of-class writing component, one which is necessary for completion of the course. I will, therefore, evaluate the success of each student's involvement with the application of quantitative methodology to the task of constructing a comparative analysis of style, not simply on the basis of the student's capacity to rexcord data (graphically or otherwise), but in the traditiopnal manner of evaluating eacxh student's ability to read, interpret and analyze a text and finally on his or her cxapacity to cast the accumulated evidence and the results of analysis of that evidence into a coherent, effectively organized prose essay.

Analytical Identification of Style - Three Parallel Texts
Exercise II (out-of-class)

Recalling the principles established in the "Preliminary In-Class Exercise" regarding the process of style analysis, take the three parallel passages given on the handout from the synoptic gospels Matthew, Mark and Luke (all of compoarable lengths) and determine by means of finite, detailed analysis (using charts, tables, graphs, whatever--be creative) how the style of each passage is distinct. You should show all your work, both the charts, tables and/or graphs and your analytical discussion of the data. Some clues toward making these determinations include tabulations of such variables as the numbers of simple and coordinating sentence constructions; the frequency of qualifiers (adjectives and adverbs); the quantity of subordinating constructions (dependent clauses, participial phrases, infinitive phrases, prepositional phrases, etc). These tabulations could be followed by representations of frequencies on graphs. Subsequently, the task here is more complex than in the class exercise; indeed, the data assembled here must be applied toward answering questions about audience and message. Is it possible to determine, without reference to external scholarship, to whom (what is the socio-economic class of the listeners? what is their probable level of literacy--their sophistication and/or education?) each is directed and what each speaker is trying to say (indicated, of course, by the style he or she or they adopt)? If you are especially venturesome, try to identify as much as you can about the speaker (what is his or her or their level of education, social class, economic status, cultural and/or ethnic affinity?).

Matt. 21:23-376	Mark 11:27-33
And when he entered	And they came again to Jerusalem
	And as he was walking
into the temple	in the temple
the chief priests	the chief priests and the scribes
came up to him as he was teaching came to him	came up
and said,	and they dais to him,
"By what authority	"By what authority
are you doing these things,	are you doing these things
and who gave you this authority?"	or who gave you this authority
	to do them?" authority?"
Jesus answered and said to them,	Jesus said to them
"I will also ask you one question	"I will ask you one question;
and if you will tell me the answer,	answer me, now tell me,
then I also will tell you by	and I will tell you by
what authority I do these things.	what authority I do these things.
The baptism of John, whence was it?	The baptism of John, was it
From heaven or from men?"	from heaven or from men?
	Answer me."
And they argued with one	And they argued with one
another saying,	another saying,
"If we say, 'From heaven,	"If we say, 'From heaven,'
he will say to us, 'Why then did	he will say, 'Why then did
you not believe him?' But if we	you not believe him?' But shall we
say 'From men,' we are	say, 'From men'?"--and they were
afraid of the multitude;	afraid of the multitude,
for all hold that John was a	for all held that John was a
prophet."	real prophet. a prophet."
So they answered Jesus and said,	So they answered Jesus and said,
"We do not know."	"We do not know."
And he said to them,	And Jesus said to them,
"Neither will I tell you by what	Neither will I tell you by what
authority I do these things.	authority I do these things."

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PROBABILISTIC AND STATISTICAL REASONING IN UNDERSTANDING TECHNOLOGY

David L. Ferguson

Introduction

In our undergraduate course on Engineering Approaches to Problem Solving, we teach liberal arts students about the quantitative methods employed by engineers and applied scientists. Given the negative (and sometimes frightening) experiences that many of these students have had with mathematics, we are confronted with a serious challenge. We want students to understand the use and abuse of quantitative models in their attempts to understand issues of personal and societal importance. There are four basic themes of the course:

- Quantitative methods can aid in making certain decisions. (Many examples demonstrate the appropriate use of quantitative methods.)

- Quantitative methods can hinder appropriate decision making. (Students must realize that "more quantitative" does not imply "better.") There are numerous examples where inappropriate formulations lead to models that are of little value in helping us to understand or predict phenomena. I have used the following example several times as an introduction to a discussion of inappropriate modelling: In the mid-1960's, a Dutch hen farmer ordered a large number of chickens from a midwestern poultry firm. He chartered a 707 jet airplane (normally holding 180 passengers and crew) to bring the chickens to the Netherlands. The midwestern firm and the airline wanted to transport the maximum number of chickens possible on a flight. The chickens averaged 2 pounds in weight, while human passengers probably averaged 170 pounds. Consequently, they decided to carry 170/2 x 180 or 15,300 chickens. (They guessed that the luggage for human passengers would approximately match the weight of the cages.)

  Unfortunately, by the time that the 707 was in the air for 30 minutes, the pilot had to land. What was wrong with the model? Some students are able to see immediately that the model does not take into consideration the difference in basal metabolic rate between chickens and humans. They are able to deduce the proper conclusion that fog became a major problem inside the aircraft. An excellent discussion of models is given in chapter 6 of the book, The Search for Solutions (Judson, 1980).

- There are many "Ways of Knowing." (Quantitative methods, art, music, poetry, etc. have different purposes and they represent different ways of knowing the world.)

- Every "Way of Knowing" has its assumption, models, and limitations.

Our Engineering Approaches to Problem Solving course is "very applied." Every effort is made to tie basic techniques to real problems of current interest to engineers and applied scientists. Furthermore, articles from daily newspapers are used to emphasize the importance of the issues to students' personal lives.

General Problem Solving Skills

Students must develop general problem solving skills. These skills should be relevant to new problems that they will encounter in the problem-solving course, as well as pertinent to many of the problems that they will encounter outside of the course. Hence, we have identified several underlying mathematical skills that we want to help students to develop:

(a) Ability to interpret graphs and diagrams (including the ability to recognize when graphs or diagrams are designed to mislead the reader).

(b) Ability to make effective use of a variety of symbolic representations.

We have found that most problem-solving courses are either filled with too much mathematical jargon or fail to handle special notations even when it is virtually essential. Most of our explanations avoid unnecessary jargon and provide a gentle and gradual introduction to symbol manipulation. Ultimately students must be able to handle a variety of representations: "real world" objects, graphs and diagrams, equations and inequalities, informal English expressions and formal mathematical expressions.

(c) Ability to use a quantitative metaphor for viewing many everyday situations.

Even though all students are familiar with waiting in lines at banks, movies, and certainly at registration booths, almost none of them have considered the quantitative dimension of these problems. This type of sensitivity to quantitative measures such as service time, arrival time, length of the queue, etc., is the beginning of understanding the use of quantitative models. Hence, we help students learn to "see" hidden structures, and begin to think about the mathematics that underlies these structures.

(d) Ability to define options and systematically analyze cases. (This ability is at the heart of much of decision analysis.)

(e) Ability to make estimates and check the estimates. (Students must be aware that many problems, especially problems in probability and statistics, may have solutions that are counter-intuitive. It is often fascinating to try to understand why human intuition is so wrong in certain situations.)

(f) Ability to develop simple models and use these models to solve problems.

(g) Ability to use a tool kit of ready-made techniques to solve problems.

The computational power of small computer systems suggests that in many cases our emphasis should be on "knowing when" versus "knowing how." If we can formulate the problem, often we can rely on applications programs to do the computations. For example, a program such as L I N D O (Schrage, 1986) can immediately solve a linear programming problem once we have formulated the problem (i.e., identified the function to be optimized and specified the constraints). Operations Research problems in general are treated extensively in several software packages (e.g., Chang, 1986).

Figure 1 shows the basic structure of our course in Engineering Approaches to Problem Solving.

FIGURE 1

Quantitative Methods

Probabilistic Models	**Deterministic Models**
Noisy Communication Channels	Dynamic Programming
Reliability in Electronic Circuits	Linear Programming
Auto Accidents	AIDS Model
Life Insurance	etc.
Quality Control in Production	
Genetics	
Drug Testing	
Gambling Games	
Inferential Statistics	
etc.	

Notice that quantitative models are divided into two classes of models: probabilistic models and deterministic models. Probabilistic models make use of random phenomena in some way. Since the outcomes of such models depend on randomness, two identical sets of values of input parameters may lead to different outputs. Deterministic models do not make use of random phenomena. Consequently, the output of the model is completely determined by a specification of the values of the set of imput parameters.

We have now established the context in which problem solving is taught in the course on Engineering Approaches to Problem Solving. In the next section of this paper, we take an indepth look at three activities that are used to teach probabilistic and statistical thinking.

The Teaching of Probabilistic and Statistical Thinking: A Look at Three Types of Activities

Students find probabilistic and statistical thinking extremely difficult. We have found that computer-based simulations, together with real-world examples, can have a positive influence on students' attitudes. We are just beginning to explore the impact of this approach on students' abilities to solve problems and analyze issues that demand probabilistic and statistical reasoning.

(A) Stock Market Simulation (Millionaire)

"Millionaire," a simplified computer-based stock market simulation, is a useful tool for helping students understand quantitative modelling (Millionaire, 1986). The "Millionaire stock market" allows the user the opportunity to play the role of investor. There are five industry groups: computer, oil and gas, retail, automotive, and heavy industry. Companies under each industry group are as follows:

Computer Industry: Control Data, Apple, NCR
Oil and Gas Industry: Conoco, Exxon, Mobil
Retail Industry: Kmart, Sears, Tandy
Auto Industry: GM, American Motors, Bendix
Heavy Industry: USS, Dow, CAT

The quantitative models that underlie the Macintosh simulation encompasses the following factors:

a) profitability of a corporation
b) changes in the number of shares traded on the stock exchange
c) news announcements about a company
d) stock price trends
e) industry group trends
f) stock market trends (bull market, bear market)
g) the company history
h) daily stock price changes
i) margin buying
j) stock option (call option, put option)

The objective in "Millionaire" is to earn $1,000,000 as quickly as possible. The computer may be thought of as a "black box." The user must study the properties of the "black box" in order to maximize profits.

The user begins with novice status; however, other levels are possible (see Fig. 2).

Two types of assignments are given to students:

a) Play the game. (Describe your tactics. Were your tactics effective? Explain.)

b) Study the model that underlies the game. What information have you gained about the model that underlies the game? (Is the model deterministic or probabilistic? How do you know?) What are the limitations of the model? (How does the model relate to the real world? How would your strategy change if you were interested in long-term gains as opposed to immediate gains? Is it practical to give an appropriate model of the stock market?)

(B) Sampling and Opinion Polls

Students who take traditional courses in statistics often have little "feel" for the more fundamental notions. In recent years several books and articles have appeared that give a gentle introduction to the use and abuse of statistical methods. (Brook, 1986; Cooke, 1985; Freedman, 1980; Gnanadesikan, 1987; Hacking 1984; Hollander, 1984; Hooke, 1983; Kotz, 1983; Landwehr, 1987a; Landwehr, 1987b; Olinick, 1987; "Millionaire," 1986; Murray, 1986; Newman, 1987; Pennar, 1985; Ross, 1986; Shaver, 1985; Tanur, 1985) All of these sources emphasize applications and concrete referents for statistical concepts.

FIGURE 2

Status Reference (Millionaire, 1986)

Net Worth	Status	Investment Opportunities
10,000	Novice	Buy stocks but not on margin
12,000	Investor	Buy stocks on margin
18,000	Speculator	Buy call options and stocks on margin
40,000	Professional	Buy call options, put options and stocks on margin
100,000	Broker	All of the above and borrow up to 80 percent of your net worth

We have used the following exercise as a vehicle to explore several statistical concepts:

Sampling and Opinion Survey

> Various polls have been taken to determine people's opinions regarding the opening of the Shoreham nuclear power plant. Assume that a local newspaper has claimed that of the 10,000 undergraduate students at Stony Brook, the proportion of students, by class level, for the opening and the proportion against Shoreham is given by Fig. 3 below:
>
> Assume that it is known that the proportion of the entire undergraduate student body represented by each class level is given by Fig. 4 below:
>
> A student group on campus wishes to challenge the student data on Shoreham that was presented in the local paper (See Fig. 3). The group is trying to decide how large the sample of the undergraduate student body must be to invalidate the newspaper's conclusion. The group has decided to use a computer simulation of the sampling to see what sample size is needed to make the sample proportions converge on the newspaper's proportions -- assuming that the proportions reported really do represent student opinion.

It is fairly easy to simulate the opinion poll by writing a program in BASIC (actually, we used True Basic). We wrote the shell of the program and had students fill in the missing details. Consequently, students were able to run the program and experiment with various sample sizes. They were able to estimate the approximate sample size needed to converge on the newspaper's results.

The computer-based simulation of the Shoreham opinion poll allowed for fruitful discussions of several statistical concepts:

a) Random sampling and representative sampling
b) Stratified sampling
c) Estimation of population parameters from samples
d) Confidence intervals
e) Hypothesis testing

FIGURE 3

	Proportion For Shoreham	Proportion Against Shoreham
Freshman	.30	.70
Sophmore	.40	.60
Junior	.50	.50
Senior	.35	.65

FIGURE 4

Proportion of Undergraduate Student Body

Freshman	.35
Sophomore	.30
Junior	.20
Senior	.15

Hence, we are able to make a connection between intuitive notions and more formal treatments (such as Byrkit, 1987; Doane, 1985; Stoodley, 1984). Design considerations for building simulations are treated in several sources (e.g. Ferguson, 1987; Gnanadesikau, 1987).

(C) Hypothesis Testing

Reports of statistical surveys are abundant in newspaper, radio and TV coverage. Hence, these media provide an excellent arena for studying hypothesis testing. Students are taught to examine reports of statistical results by examining the following components of the reports:

a) Surveys. (How were the questions asked? Would an alternate wording have been better? Did the order of the questions influence the results?)

b) Inferential Statistics. (Inferential statistics is the science of drawing conclusions about a population based on information about samples from the population. Inferential statistics can be a powerful tool for making decisions in light of uncertainty.)

c) Interpretation of Results. (Two researchers who are confronted with the same statistical results may have grossly different interpretations of the results. Students should be able to disentangle purely statistical conclusions from the interpretations given by researchers or news reporters.)

d) Conjectures. (When statistical results are reported, the writer often makes conjectures that are not supported by the data. Such conjectures may attempt to offer a rationale for the statistical results. Students should be able to identify such conjectures. It is important to form one's own opinion of the reasonableness of such conjectures. It is also fruitful to consider how the validity of these conjectures might be tested.)

Samples of newspaper articles that I have used to develop basic ideas of hypothesis testing are given below. Some issues are clearly controversial, while others represent a clear abuse of statistical methods.

a) It was reported in the school newspaper that college placement offices help. The basic argument given was as follows: $21,000 per year was the average salary of students who used the college placement service, while $15,000 was the average salary of students who did not use the service.

b) Doctor claimed that a drug commonly used for hypertension dramatically increased SAT scores.

c) Study shows more people are afraid to fly.

d) Death rate from AIDS found to vary as a function of initial type of infection, sex, race/ethnicity and age.

Many other articles have been used in the course. Some of the more interesting reports have been discovered by students in the course.

Conclusion

Many problems have a quantitative dimension. We have looked at how probabilistic and statistical thinking can be developed in the context of helping students to understand modern technology and its impact on society. We have drawn examples from a wide range of fields.

Key components of our pedagogical approach are as follows:

- Start with interesting and captivating applications. (Each topic begins with the statement of a problem that is of interest to students.)
- Develop mathematical techniques in the context of real problems.
- If appropriate, use computer-based exploratory environments to allow students the opportunity to "play" with mathematical models.
- Involve students in reading and interpreting articles in newspapers and other publications that exhibit a strong quantitative content.

This pedagogical approach has been used in our teaching of Engineering Approaches to Problem Solving. In particular, we have used these strategies to help students develop the abilities to do probabilistic and statistical thinking.

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A REVIEW OF COMMUNITY COLLEGE STS CURRICULA: MOTIVATORS AND CONSTRAINTS

Corrinne A. Caldwell and James P. Hamilton III

Half of all initial post-secondary students enroll in community colleges. For most the associate degree will be the last. The burden of providing a well balanced general education weighs heavily on community colleges. Curricula aim at skill development leading to immediate employment. Community college students do not enjoy the luxury of sampling and discovering areas of interest. Students typically select a rather rigidly prescribed curriculum and adhere closely to the basic degree requirements. Graduates of non-science programs have very limited exposure to science courses; graduates of technical curricula, though exposed to science as it relates to their particular technology, have very few, often no liberal arts courses to balance their technical courses.

Despite this narrowness of educational experience, community college graduates both purvey, and in many cases, translate technology to their communities. In a time of increasingly complex technology, society may depend on technicians who had no opportunity to consider the wider societal implications of their work. The prospect of skilled installers, repairers, even developers of technology working in an historical, sociological, and values vacuum is daunting.

Society can not readily rely on the graduates of baccalaureate programs for scientific edification. Surprisingly few college graduates have undertaken more than the minimum science requirements or have taken integrative courses linking science and society. Such ignorance threatens not only the scientific community but also the core of democratic foundations. Paul Gray, President of Massachusetts Institute of Technology, commented:

> The M.I.T. physicist Philip Morrison has described the likely consequences of continued public ignorance of science. "If we cannot promote the growth of a wider understanding of the world view of science and technology, we endanger not only our own abstract enterprises, but even the essence of democracy.....For the necessities of economics will eventually enforce a social division into islands of the trained, who understand enough to devise and operate an increasingly complex technology, within a sea of onlookers, bemused, indifferent and even hostile." (Gray, 1988)

And an Oberlin professor of Biology, Michael Zimmerman, sounded the alarm thus:

> We do have a pressing problem when people take Fred Flintstone more seriously than Carl Sagan. Scientific and technological advancements are based on knowledge rather than mere opinion. As a society, we put ourselves in a precarious position when we do not have a solid core of basic scientific knowledge; we weaken

> the quality of our technological decisions while increasing the potential for political abuses in the name of science. (Zimmerman, 1987)

The juxtaposition of increasing concern about the adequacy of the science-and-society education of community college graduates and the need for increasing scientific knowledge for effective participation in democracy, prompted the study described in this paper. The underlying questions were:

1. Do community-college curricula prepare graduates to become skilled technologists with a well developed understanding of the implications and context of their technology?

2. Do community colleges require or even provide for the scientific literacy of their non-technology graduates?

Offering and requiring courses in science, technology, and society can answer both questions positively. Courses in science, technology, and society (STS) for the purpose of this study, are basically science and/or humanities courses. In the former, science instruction includes material exploring technological applications or social implications. In the latter, courses approach science and technology with the perspective and techniques of the humanities disciplines. Examples: History of Science, Technology in Literature, and Philosophy of Science.

STS courses are not the only approach to answering these questions. Many other fora have eloquently and forcefully made the case for additional pure science and humanities curricula. However, STS courses have the advantage of an integrative and contextual view of science, which other approaches do not share. This study proceeded with the underlying assumption that STS courses were one significant way to provide for the science literacy needs of community college students.

This study consisted of an analysis of data collected from a questionnaire sent to all members of the American Association of Community and Junior Colleges asking for information about STS offerings. (The questionnaire will be described in detail later.)

The previous evidence of community college participation in STS type curricula is meager. James Williams reported in 1986:

> Science, Technology and Society began as a conscious discipline seventeen years ago. By the mid-1970s, a Cornell university guide to the field reported some 400 institutions, 100 programs and 2000 courses dealing with STS. Today while not all the courses identified by Cornell continue to exist, STS remains a strong area of study in four-year colleges and universities. This is unfortunately not the case in community colleges.
>
> The 1975 Cornell guide identified only 29 two-year colleges offering STS courses. In 1980 the Technology Studies and Education Committee of the Society for the History of Technology (SHOT) sponsored a survey of 820 public two-year colleges and received a 19% return. It revealed only 39 colleges offering STS courses, three of which were two-year campuses of state universities and 16 of which had been listed in Cornell's study. None of the responding colleges offered what might be called an STS program.
>
> The SHOT survey reported only 52 STS courses, some of which were only vaguely related to STS. Thirty-five dealt with science/technology and society,

> "environmental studies" and "history of science/technology". The rest were scattered offerings in philosophy, science, computer science, "future studies" and film classes using James Burke's "Connections" and Jacob Bronowski's "Ascent of Man" series. There were no common texts or audiovisual materials cited. The courses had a median enrollment of 25, half of the courses were offered only once each year and 70% were elective courses. (Williams, 1986)

This study attempts to move beyond recording changes in the number, type, and scope of STS offerings to an understanding of the forces which motivated or discouraged implementation of STS curricula. The survey was designed with this larger goal in mind.

The survey began by collecting demographic information. The authors hypothesized that the demographic characteristics of the college and the community served might be significant variables in relation to the offering of STS courses.

The survey continued with the respondents describing STS courses at their institutions. Although STS was defined, the instructions encouraged respondents to submit details about any offering falling under their own, as well as the study's, broad definition of STS. Previous studies had demonstrated inconsistent, even erratic, classification, naming, and assignment to departments of STS courses. The authors allowed for the broadest possible latitude in self-definition, while at the same time collecting enough information for a decision on the eventual inclusion of the particular course as an STS course for the purposes of the study. A detailed description was also necessary for the development of a taxonomy of responses.

Survey studies do not make ideal vehicles for determining motivation. Nevertheless, the remainder of the questionnaire was devoted to this end. It asked respondents to answer two closed-end questions about possible motivators and inhibitors to the offering of STS courses. The choice-items came from previous research and conference discussions.

The interest of a particular faculty or staff member had surfaced as a major motivator and, conversely, the lack of such interest as a great inhibitor to STS development. Faculty work within institutional structures which vary widely in their support or inhibition of STS efforts. Frequently, individual faculty initiatives encounter a system which chronically underfunds faculty development and underestimates the amount of time required to develop and implement new curricula. New programming demands extensive, expensive faculty time and efforts. Faculty lack of exposure to STS exacerbates the problem. Justifiably unsure of their skills in this area (even if personal interest exists), they shy away from tackling a new and demanding subject. (Caldwell, 1987)

The intellectual and cognitive demands of existing community college curricula present a legitimate barrier to the implementation of new courses or curricula. Community-college faculty and staff already face a formidable task in preparing frequently marginal students for demanding technical careers in a reasonable time frame. While curriculum planners may philosophically embrace the notion of STS, inclusion of STS in an already tight and onerous curriculum is a daunting task.

For any program, success means sustained student demand. Without student support, the offering will lanquish and die. Overwhelming support of STS by faculty and staff will make no difference.

Curricular initiatives often originate from regulatory or state agencies. Some STS curricula development have resulted from such external intervention. New Jersey recently requested, then funded selected proposals for STS curriculum development. Though still difficult to assess either the quality or long-term effectiveness of these externally motivated efforts (Kinnamon, 1988), the effect of external agencies appears in the questionnaire.

Methodology

In October of 1987, 1023 questionnaires were sent to members of the American Association of Community and Junior Colleges. The forms solicited information about the type, size, and mission of the institutions, whether or not STS courses were offered, the nature of such courses, and the reason that courses were or were not offered. A reminder in the form of a post card followed in December 1987. One hundred fifty-one usable questionnaires returned, producing a return rate of 14.8%.

Results

The first item set on the questionnaire sought information about the responding institutions, including: type of institution, size of the student body, and the primary mission of the institution.

TABLE 1

INSTITUTIONAL PROFILE OF RESPONDENTS

Institutional Type	#	%
Junior College	26	17.2
Community College	113	75.0
2-Year Campus of 4-Year Institution	7	4.6
2-Year Technical	4	2.6
Public	139	92.0
Private	12	8.0
Primary Mission		
Terminal Degree	17	11.2
Transfer to 4-Year	13	8.6
Both (terminal + transfer)	114	75.5
Other	7	4.6
Size of Institution (full-time + FTE)		
0-3000	98	66.6
3001-6000	20	13.6
6001-9000	18	12.2
9001-12000	2	1.4
12001-15000	3	2.0
15001-18000	2	1.4
18000+	4	2.7

The second set of questions asked the extent to which STS courses were offered, whether they were listed as science of humanities courses, who taught the courses, and who took the courses. The form described the nature of STS courses and gave some examples that might help them to make a better determination of whether or not any of their courses qualified. It also asked them to include any courses about which they were not sure so that the authors could make a decision. Additionally, it asked for course descriptions and syllabi if possible.

TABLE 2

TYPES OF STS CURRICULA REPORTED

Do you have a curriculum in STS that could be identified as a(n)?

Major	1	.9%
Minor	1	.9% (same school listed major and minor)
Emphasis	1	.9%
Neither the school listing a major and minor not the school listing an emphasis listed any courses.		
Isolated Courses	73	48.3%
No Courses	76	50.3%

Table 3 describes the analysis of reported STS courses to determine if they are truly STS, their academic affiliation, who teaches the courses, and who takes them.

TABLE 3

COURSE PROFILES BASED ON COURSE DESCRIPTIONS

STS Courses	32	16.9%
Courses With Probable STS Components	23	12.1%
Non-STS Courses	134	71.0%
	189	100.0%

DESCRIPTION OF COURSES DETERMINED TO BE STS

Listed as science courses	34.0%
Listed as humanities (soc. sco.) courses	66.0%
Taught by science faculty	52.2%
Taught by social science faculty	43.5%
Team taught	4.3%
Taken by science majors only	4.3%
Taken by non-science majors only	39.2%
Open to all students	52.2%
Taken by honors students	4.3%

The last set of questions asked the motivations and constraints that administrators and faculty might feel towards offering STS courses.

TABLE 4

MOTIVATIONS AND CONSTRAINTS

Motivations For Offering STS

Interest of a particular faculty member	38.6%
Concern about science and technological literacy of non-science students	36.0%
Concern about the general education needs of science students	31.3%
Student demand	22.0%

Availability of a grant to support curriculum development and implementation	10.6%
External government or accreditation pressures	6.8%
Other	6.0%

Constraints On Offering STS

Pressures of other courses in existing curricula	50.6%
Scheduling in existing curricula difficult	31.3%
Faculty unprepared for teaching STS	30.6%
Lack of student interest and enrollment	30.0%
Lack of internal funds for new course development	22.6%
Lack of support by science faculty	16.0%
Lack of support by non-science faculty	12.6%
Lack of support of external funding agencies	12.6%
Lack of support of accreditation agencies	8.0%
Lack of support of administration	6.0%
Other (mostly transferability concerns)	8.0%

Discussion

The first set of questions categorized the respondents into certain substantial majorities, viz., 75% community colleges, 92% public institutions, 77% with fewer than 5,000 students (full-time + full-time equivalents), and 75.5% having both terminal (associate-degree) and baccalaureate transfer missions (Table 1). Initially, the study intended to analyze the differences (if any) between institutions of varying sizes, types, missions, and affiliations, but too few responded in other categories to permit reliable comparisons.

Among the respondents to the second set of questions, 50.3% said that they offered no STS courses; 48.3% that they did. The positive respondents listed 189 course titles and/or descriptions for analysis. Of the two remaining institutions, one claimed a major and minor, one claimed an emphasis, but neither listed courses or sent descriptions to support this (Table 2).

Under scrutiny, only 16.9% of the listed entries qualified as STS courses under the definition provided by the authors on the questionnaire. Another 12.1% appeared to have an identifiable STS component. But the remaining 71% clearly had little or no basis for STS standing (Table 3). The incorrect listing suggests considerable confusion over the nature of STS courses. Some colleges included courses utilizing innovative pedagogical technology (e.g., computer assisted English composition). Most often, however, they simply named traditional science courses (e.g., biology) which spent a period or so on social implications of such new technology as gene-splicing.

Where the courses did qualify as STS, two-thirds were identified as social science or humanities courses, the remainder as science courses. But in spite of this 2-1 social-science/humanities preponderance, 52.2% of the courses were taught by scientists, 43.5% by social-scientists or humanities, and only 4.3% by interdisciplinary teams (Table 3). Scientists, therefore, seem more likely to teach social-science STS courses than social scientists are to teach science STS courses.

Most truly STS courses (52.2%) welcome all students, but when restrictions do apply, admission tends to favor non-science majors (39.2%). The remaining 8.6% divide STS courses between science majors and honors students (Table 3). Colleges perhaps perceive the need for greater scientific and technology literacy greater among non-science students than among those in science.

The third set of questions explored why institutions felt motivated to offer STS courses and what constraints made offering them difficult. Interestingly, many of the institutions without STS courses indicated why they felt that they should have them. The strongest motivating factor (38.6%) was the interest of particular faculty, closely followed (36%) by concern for the scientific and technological literacy of non-science students. Next (31.3%) came concern over the general-education requirements for science students (which might explain why so many STS courses bear social-science or humanities titles) and fourth (22%), student demand.

The greatest constraint reported (50.6%) was the pressure of existing curricula, which makes insertion of STS courses a major task. The second (31.3%) ties into the first: the difficulty of scheduling such courses, given the demands of the existing curricula. About 30% cited lack of faculty preparation and lack of student interest/demand, and about a fifth (22%) lack of internal funds (Table 4).

Implications and Recommendations

Four major recommendations emerge clearly from the data this study produced:

1. Clarify the definition of STS and STS courses in future studies and in promotion of the STS concept.

As noted in the tables and discussion above, only 16.9% of the courses listed as STS actually qualified as STS in spite of the definition provided by the questionnaire. Unless faculty and administrators clearly understand STS as a vehicle for building scientific and technology literacy among non-science students and the social implications of science and technology among science students, they will not adopt the concept — particularly in view of the contraints found among community college respondents.

2. Promote STS through individual, interested faculty.

Respondents reported the interest of particular faculty members as the greatest motivating force they recognized for an STS program. Such faculty can make a difference, and direct support of that interest could help them. Example: STS materials designed for faculty in various disciplines (rather than generalized items) might help them convince colleagues and their administrators. Future studies might look at the relationship between the faculty efforts (vis-a-vis STS) and the reward structure of the institution. While such efforts comprise the most significant reason for institutions' offering or developing STS programs, this will likely end if such faculty are not recognized within the reward system (salary, promotion, and tenure, etc.).

3. Expand STS instruction via components rather than through courses, emphases, or majors.

Respondents identified two major, related constraints in adding STS courses: the pressure of existing courses in the curricula and the difficulty of scheduling additional courses. Indeed, adding courses to crowded associate-degree programs and cluttered timetables is a major problem for faculty and administrators seeking to keep degree programs up-to-date. Efforts to promote STS might prove more successful if focused on integrating STS material into existing courses. Five 20% integrations, for example, would add up to a full course. And five attacks points (as opposed to one) could provide the same integrative force — perhaps more — than a single course. Colleges might be willing to go this route rather than undertake the major effort of inserting a new courses into present programming. Future studies might examine the application of STS courses to technical proficiency in various vocational situations and how beneficial STS courses or components are perceived in that regard.

4. Consider other methodologies in future studies.

Low return rates plagued both this study and the previous Cornell study. A different approach might increase response and with it, reliability of the data. One can speculate that non-respondents had nothing to report; that is, they offer no STS programming. This would create a more dismal picture than this study reports. But it is speculation, and more data must be obtained.

Although the results of the study do not substantiate increased activity in STS at community colleges, they do provide the basis for some important recommendations about STS initiatives and future direction. A vital STS program in community colleges requires a marshalling of individual and collective efforts on a much greater scale than at present, if "graduates are to understand how to use science and technology sufficiently to contribute knowledgeably to public decisions" (American Association of State Colleges and Universities).

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INTEGRATING STS SHORT TOPIC ACTIVITIES INTO PRE-SERVICE TEACHER TRAINING

Jack E. Fletcher

In the 1985 NSTA Yearbook, Irma Jarcho provided an overview of the kinds of courses being offered at the pre-college level. Five categories were listed as being representative of the various curriculum approaches to teaching STS. The focal point of STS activity should be pre-service rather than in-service teachers.

The content and materials to be presented in a Methods course is determined by the instructor. In contrast, much of what is to be taught in the public schools is determined by established curriculum, textbooks, and/or local and state agencies. Methods students, having once worked through an STS (or other) exercise, and possibly having presented it in a microteaching situation, would, in all probability, use the material and teaching strategy when they are in their own classrooms as teachers.

Although I do not have data to prove this, I have found that many activities from my Methods course are incorporated into the public school classrooms. The most immediate is during the Methods course, when four lessons must be developed and presented by the student in a public school classroom.

The Student Teaching experience has been another vehicle for presentation of STS (and other) activities derived from the Methods course. On many occasions Master Teachers have called and asked for additional activities and lessons being taught in Methods.

A review of Jarcho's five categories lead the author to the conclusion that the Short Topics could be incorporated into Methods. The two examples given are the Technology Infusion Project, which contains numerous student activities over a variety of technology topics; and Infusion Tips written by Richard Brinckerhoff. These are a collection of short items, each consisting of a short series of thought-provoking background statements followed by related questions on STS issues. Advantages of the infusion approach include "ease of use, ready availability, and minimum interference with the standard curriculum ... The short topic approach also makes it possible for teachers who have no previous experience teaching STS topics to try teaching their material ..."

The problem of incorporation into my existing Methods course appeared to be twofold:

l) The majority of my current Methods students have had only the minimum number of Science (two) and Social Science (two) courses as part of their General Undergraduate Requirements (GUR). None of the four courses is required to be a laboratory course. The students are primarily Elementary Education and Reading majors; majors which are areas of state endorsement for employment in teaching. To help compensate for this lack, a one-credit-hour laboratory course is mandated for the Methods students to provide hands-on experience.

2) The incorporation of the two different subject areas into a single-quarter Methods course is a monumental task, still being modified. It is not the purpose of this paper to outline the process of integrating the two, other than to say there are several underlying themes, teaching strategies, and processes common to both.

The development of a series of short topic activities that would last for one class period each seemed a natural for my situation. The ideas outlined by Jarcho parallel teaching strategies I have been using for years in my Biological Science and Science Methods Courses. Two of the most successful have been "Controversies in Science," similar to Infusion Tips, and "Invitations to Inquiry," a modification from the original BSCS. The processes of presenting material remains the same. The content is easily modified to accommodate STS. My "Controversies in Science," which has proven sound throughout the years, has become "STS Controversies."

STS Controversies

My stated purpose is to make the student aware of the personal ramifications of science and technology and their effects upon society and/or the environment, and to cause some type of value judgment. The Controversies usually begin with presentation of direct information, historical or contemporary, or an event which is outside the normal sphere of textbook learning, but which could have (had) great direct or indirect implications for life in the future. If it is to be a true controversy, both sides of the issue must be presented and with as much objectivity as possible.

The sources of information must be reliable and may vary from newspapers and magazines (Smithsonian, American Heritage, etc. are excellent) to research findings. The information may be in the form of handout to be read by students; read by the teacher (me) to students (tape and video recordings prove satisfactory); or presented by overhead transparency (especially graphs, charts, etc.). I try to limit each controversy's materials to approximately one page with emphasis on the discussion following and not on the reading or presentation. Discussion, limited to clarification during the reading or presentation, should not contain closures, and agree-disagree finalities are out.

My objective then is to stimulate the discussion, after the data are presented, to the furthest extent of the ramifications imaginable, and not to agree or disagree with students' value judgments or force any value judgment upon them. I may summarize i.e., "the class seems to think ...;" "the majority seem to agree ..." However, I leave each student with his individual judgment.

As a summarizing activity the "STS Interactions Triangle" is then visually presented. Major points previously brought up by students are placed upon the triangle in the appropriate STS category, and interactions are noted and discussed.

In order for students to become accustomed to using the process, I begin with an historical controversy -- that is, one that happened in the past, where decisions are already made. Thus, some consequences of those decisions can also be introduced, because at least some of the consequences are still with us. An example of this first kind of controversy, where some outcomes are known, is "The Introduction of the English Sparrow into America."

"The Great Sparrow War" is a colorful account of the introduction to and subsequent spread of the English (House) Sparrow in America. The reasons for its introduction and several decades later its unsuccessful eradication are outlined. Not only did its introduction divide the ornithological community, but communities across America. The Sparrow's rapid expansion due in part to the distribution of railroad grain cars; its decline to an "acceptable" level with the introduction of the automobile; and finally its declaration early 80 years later by the ornithological community complete the article.

The article spawns great controversy in the classroom, with much of the conversation centering around the major role played by societal decisions which overrode the judgment of scientific experts. I write on the board SOCIETY. When the conversation brings in TECHNOLOGY, it is added, with arrows going both ways. SCIENCE is soon added to complete the Triangle. We discuss the Triangle and how clearly the interactions are represented. This leads to how they can use this "triangle concept" in discussing issues in the elementary school.

At the next opportunity I introduce a more complex controversy, which has elements of both historical and future implications: "DDT - a Continuum." Discussion begins with the pros and cons of DDT usage, then centers around the decisions worldwide to ban DDT; the pros of growing pyrethrum: the Third World cash crop necessity (i.e. marijuana and opium poppy, etc.); the destruction of habitat for the primates; the continued practice of clearcutting; and the future implications of depleting the world's forests. Students are brought to the realization that continuity and change are an important element in the process.

The second strategy that I use is called "Invitations to STS Inquiry." My stated purpose is to familiarize students with a basic scientific concept or principle. These same basic hands-on activities are also included in current elementary science textbooks. My assumption is that if she/he does it in Methods class, she/he may teach it.

The next step in the process is discussion, which follows the hands-on activity, of all the various student-known applications of the principle. Additional materials for further hands-on experimentation, a teacher demonstration, and/or written or graphic information is provided to students to widen their knowledge about the principle and its applications. This usually stimulates further discussion during which students arrive at examples of even more technological applications.

Examples of the technological applications are looked for in history along with their known effects on society. These examples are placed upon the STS Interaction Triangle. Discussion of the applications of the technology or the scientific concept to the future is a concluding activity.

One example is based upon the concepts of adhesion and cohesion. I begin with a handout on the necessities of lead shot to the settlers of early America. I then have every student examine a drop of two different solutions (water and alcohol) on first waxed paper, and then on aluminum foil. Observations of characteristics are noted. Drops on one material remain more round. Through more experimentation the concepts of adhesion, cohesion and surface tension are developed.

Student-provided examples of applications of each of these concepts are listed on the Interaction Triangle. Some examples are: glue for surgery, auto wax, detergent on pond water, etc. and finally to the making of lead shot by dropping the molten lead from a shot tower. We conclude by looking at the circular shape of liquids in space.

Before closing I would like to mention two other class activities that I have found to be very constructive in developing the STS theme. One is titled simply "Islands." Having taught in Micronesia, a group of islands north of the equator and west of the International Dateline, I begin by presenting a slide program of those islands as part of Social Studies Methods. Micronesia includes a variety of governmental forms: territory, commonwealth, federation and one independent republic. Time is spent discussing their status in the world as newly-emerging countries. We cover such topics as basic economies, natural resources, employment and education. Because the students can easily comprehend an island entity, these topics are at least superficially more readily understood than, say, for a country on the continent of Africa.

The lesson is closed with me providing the students with a real address of the Department of Education for each of the island groups, and their writing a letter (for use later when teaching) asking to establish a "pen-pal" relationship with their particular grade and school.

The second class activity I want to mention is my students are required to participate in two live satellite teleconferences, so that they will have a feel for "high technology" in their future classrooms. E.W.U. has some of the newest equipment for both UPLINKing and DOWNLINKing.

Concurrent with my Methods class, students are in the elementary schools two full days each week and teach four (4) Science/Social Studies lessons during the quarter. Lesson plan development for the four teaching sessions is part of my Methods class requirements. I further plan to have as many as possible of my students teach from the STS material their lessons in Science/Social Studies in the elementary school. Teaching a lesson from ST Week teacher materials (Job-Bot, etc.) creates further interest in understanding the need to incorporate STS into the curriculum. I already have had students who will be student teaching this coming April asking for a copy of the materials and a workshop.

James R. Geise states "while preservice teacher training is no panacea for STS, we must keep in mind that most teachers today have been teaching a long time, and that the experts are estimating that one million social studies teachers will begin their service in the next five years. We therefore must consider innovations in preservice teacher training consistent with the innovations being considered for the curriculum."

In our Spokane School District, the second largest in Washington State, it is estimated that 50% of the present teachers will be eligible for retirement within the next five years. It is my recommendation that if we are to have the greatest impact on the largest number of beginning service or pre-service teachers, with the least amount of dollar expenditure, there should be workshops for the training of college level Methods teachers, in the areas of Science and Social Science, at both elementary and secondary levels. These could take place in convenient times; i.e. summer, spring break, pre-fall. This kind of schedule would not intrude on either teaching or vacation time.

The rationale is that Methods courses, at least in elementary teacher training are usually required of all students regardless of major or minor. If I may use myself as an example, I teach 250-300 elementary majors per year. Approximately half will be teaching upper elementary or middle school -- many of them by Fall 1988. I also recommend the development of materials for college Methods instructors to use (developed perhaps by a writing committee) to produce a "companion" booklet of practical materials, giving guidelines on the use of techniques and actual exercises which could be used along with existing Methods texts. I have outlined some possibilities in this paper.

The focal point should be pre-service rather than in-service. If there is "no room" to incorporate STS into existing curriculum, then we must train or imprint teachers to recognize or to think in terms of STS relationships automatically.

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AN STS TEACHER EDUCATION COURSE FOR MIDDLE SCHOOL SCIENCE TEACHERS

William J. Doody and Dianne Robinson

STS Education is vigorous and growing. Participants at the Third National STS Technological Literacy Conference witnessed the inaugural meeting of the National Association of STS, and STS is now an integral part of the science syllabus in several states. Pre-service teacher education is one area where significant change is occurring as a result of the STS movement.

For the past two years Hampton University and SUNY Potsdam have been developing Model Pre-Service Programs for the preparation of middle school science and mathematics teachers. Three types of new courses have been created: 1) college level science courses with an STS component; 2) a liberal arts STS Studies course; and 3) an STS Science Education course. This latter course will be discussed in the remainder of this paper.

STS Science Education is distinct from traditional STS Studies and traditional Science Education in goals, content, and techniques. STS Studies draws upon the domains of sociology, history, philosophy, economics, anthropology, natural science, and technology; it focuses on understanding the dynamics of STS interactions. In contrast, STS Science Education draws upon the domains of science education (pedagogy and cognitive science), the natural sciences, and STS Studies; it focuses on affective outcomes and knowledge of science in the context of society. STS Studies and STS Science Education each has a distinctive set of goals and a unique place in an undergraduate teacher preparation program.

Goals

STS Science Education has four goals. These goals are derived from the **Project Synthesis** report on science education (1). The first is titled **Personal Needs**. "Science Education should prepare individuals to utilize science for improving their own lives and for coping with an increasingly technological world". The second is titled **Societal Issues**. "Science Education should produce informed citizens prepared to deal responsibly with science-related societal issues". The third is titled **Academic Preparation**. "Science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge appropriate for their needs". The fourth is **Career Education/Awareness**. "Science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests". These four goals are best pursued in a learning environment which pursues knowledge of science in its social and technological contexts.

With that understanding, the goals of science education and STS Science Education are synonymous.

STS science education addresses Personal Needs by providing opportunity for students to perceive science and technology as vehicles for improvement of their own life. Understanding of the dialectic between science, technology and one's own life is a first step towards developing a sense of control over science and technology. That sense of control is fundamental to the actual use of science and technology to address Personal Needs. Development of a positive attitude towards science is also required for attaining this goal. Science must be perceived as relevant to fulfilling personal needs and susceptible to management if an informed positive attitude towards science is to be developed. Persons who understand STS dialectics and have an informed attitude towards science are thereby empowered to use science to address personal needs.

Societal Issues in a technological society are addressed when citizens have a value system which motivates them to participate in science related decision making and policy setting. Science educators must provide for the development of valuing skills, issue identification, and decision making skills to enhance the quality of science related policy setting. The development of such skills is a mutual concern of STS Studies and STS Science Education, but each discipline differs in its' focus on this issue. That difference is significant when considering middle school students. STS Science Education addresses this difference.

STS Studies traditionally focuses on understanding the interactions of science, technology and society. Attention is given to societal problems which are the consequence of applied science, as well as many other significant issues. The principle focus is on scholarly understanding of STS interactions, which provides a knowledge base for value setting, issue identification, and decision making. STS Studies does not focus on topics of intellectual development and pedagogy. Knowledge of these is essential to manage the development of skills among middle school students, and STS Science Education addresses that need. Middle school science teachers are charged with developing STS related skills in the context of teaching science. The middle school teacher must be able to identify student's levels of science competency and social maturity, and select STS issues which are appropriate for skills development of pre-adolescent and adolescent students. An STS teacher education course must enable teachers to understand age related development of science process skills, maturing concepts of society, and age related conceptualization of STS issues. It must also develop competency in effective instructional techniques. Such a course enables teachers to attain Project Synthesis goals for science education and competency to understand STS issues.

Content

The content of STS Science Education is broader than traditional science education. First it includes STS issues. Second it is concerned with the development of skills required for active participation in a complex technological society.

The 1985 N.S.T.A. Yearbook Science-Technology-Society contains an excellent collection of articles on STS issues and skills. Articles on STS issues include the "Historical Evolution of Invention and Discovery"; "Scientific Progress and Public Policy"; "Social Implications of Science and Technology"; and "The Changing Concept of Scientific Observation". Topics associated with development of skills include "What Should the Scientifically and Technologically Literate Person Know, Value, and Do As A Citizen?"; "Science Curricula in Preparation for Social Responsibility"; and "Charting a Course Through Risk and Controversy: Strategies for Science Teachers".

Several themes run through these topics. One focuses on the historical evolution of science and technology and society. This theme examines the evolution of western society, and reveals that applied science and technology may produce desirable, undesirable, or mixed outcomes. Another theme examines connections between personal values and social responsibility. The links between personal values, social responsibility, and management of science and technology are poorly developed for many people. Yet the need for public participation in making public policy is increasing rapidly. Increasingly, voters must choose how and where to use technology to accommodate personal and societal needs. The challenge of STS Science Education is to develop competency to assume social responsibility in science related public issues. An STS science education course must prepare teachers who are in touch with current STS issues and who are creative in finding new ways to bring age appropriate issues into the classroom.

At the middle school level, appropriate content should be found in the context of the local environment. STS issues should engage students in activities which are interesting, and engage them in the process of developing the meta-cognitive skills of values clarification, issue identification, and decision making.

A teacher of science has responsibility to develop the knowledge, skills and problem solving abilities specifically associated with science. This responsibilities is not diminished by the orientation of science education towards STS. The STS science teacher has an expanded set of educational objectives which include development of STS related meta-cognitive skills. STS science education must therefore prepare teachers who are aware that they are change agents, with the consequence that they will have to play some role in the adjustment of peers, administrators and parents to STS science education. Testing and accountability is one area in which adjustments from traditional practice need to be made.

Standardized tests of achievement are frequently used as a measure of success in attaining educational objectives. Performance on these tests is indicative of knowledge of science and technology but does not adequately STS related meta-cognitive skills. Often, scores on achievement tests are used to evaluate school and teacher performance, and preparation for achievement test performance sometimes becomes a "de facto" educational objective. This sets up a situation where there may be conflict between traditional assessment and assessment appropriate for STS science education.

Development of meta-cognitive skills in the classroom requires flexibility and creativity in the classroom, whereas the amount of factual knowledge learned by students increases with rote techniques. A characteristic of STS skills is that standardized answers are not desirable, while factual knowledge is standardized. In an STS learning environment each individual student develops mature values clarification, issue identification, and decision making skills which reflect his/her unique background and goals. Students are encouraged to express considered personal opinion whereby they nurture the development of the skills necessary to participate in a technologically complex society. The STS science teacher thus has a set of objectives which go significantly beyond the attainment of knowledge, and must establish a system of testing and accountability which reflect that.

Such a system should assess such attributes as creativity (2), which is a characteristic of good scientific thinking as well as mature social thought, and attitude towards science, as well as the STS related meta-cognitive skills. This expansion of testing to new domains does not imply deletion of testing for the acquisition of scientific knowledge. STS science education focuses on developing understanding of science content and processes, and may be expected to excel in attaining this objective. Assessment of understanding is, however, much more difficult than testing for recall of factual information and there is not common agreement on the effectiveness of standardized tests in this regard. To compound this difficulty, STS science educators may be expected to vary from one another in the topics they cover from school to school as they focus attention on topics of local interest. Standardized tests which are used over wide geographic areas require a standardization of content. An STS Science Education course must prepare teachers to have the competency to develop understanding of science and STS in a flexible learning environment, to have the competency to demonstrate their effectiveness in attaining their goals, and to work as change agents in establishing a system of accountability within their school which accommodates their objectives.

Technique

STS Science Education requires that new pedagogical techniques be added to the science teachers repertoire. Specific techniques are necessary to develop values clarification, issue identification, and decision making skills. If these techniques are to find their way into the classroom it is necessary to reconsider the role of the teacher. An STS science education course must educate teachers who understand the evolving nature of the profession of teaching and who have the flexibility to grow and improve as the profession matures. These teachers must be prepared to gradually assume increasing amounts of responsibility and authority for development of STS science programs as school systems increase their reliance upon teachers, as recommended by A Nation at Risk and other reports.

The effectiveness of placing the authority and responsibility of program development in the hands of professional public school teachers is well documented. Over five years, the Iowa Chautauqua Program has brought teachers together and provided them with a STS forum for interaction. A network of lead teachers has evolved. These leaders are infused with the philosophy of reaching out for new ideas from others, and including others, in a common quest for excellence in STS science education.

An important step in development of issue identification and STS problem solving skills is provision of opportunity for students to use these skills. Role playing and group simulations are techniques which can be used to have students actively practice the use of these skills. Examples of using these techniques may be found in Project Wild, developed by the Western Regional Environmental Education Council. Many of the activities in the Project Wild teacher's guides call for students to assume the roles of different interest groups, define values as they choose positions on an environmental issue, clarify the issue through discussion, and then reach a group decision. An STS science education course should familiarize teachers with resources which support STS science education, provide experience with the use of such materials, and demonstrate practical techniques for developing appropriate skills.

A model STS science education learning environment focuses attention on meta-cognitive skills as well as traditional science knowledge and skills. Instructional techniques particularly suited to development of meta-cognitive skills are well known. A sample technique is that used in the development of valuing skills.

Values, more so than Attitudes, are not the product of teaching but the product of personalized activity. Instructional strategies for development of values clarification skills provide opportunity for students to evolve their own values. The technique is straight forward. First, the teacher must distinguish between learning environments designed for learning of facts, learning of concepts (broadly defined to include processes), and development of valuing skills. Learning environments which facilitate development of values clarification skills include a three phase process of Choosing, Prizing, and Acting. Students exercise free choice, selecting from options, carefully considering the ramifications of each option. Students are provided opportunity to cherish the choice, and publicly affirm it. Finally, students do something with the choice, allowing one's life to be affected by it. Environmental education activities involving role playing, where students become actively involved in the simulation of an environmental problem, provide a practical example of how to engage middle school students in meaningful learning. In such activities, students express opinions, define values, identify new issues, and make decisions while learning science. Research shows that this technique is effective. Given multiple opportunities to develop values relevant to STS issues in the classroom, students may be expected to demonstrate increased activity in developing values relevant to STS issues outside the classroom. Similarly, issue identification and decision making skills may also be developed in the classroom environment. In designing instruction to develop these skills, a teacher must be familiar with a variety of techniques framed within a model of growth and development which describes the relation between the concept of self and the concept of society at various age levels.

Kohlberg's model of the development of moral reasoning provides an excellent framework from which to understand the evolving relationships of these concepts during the middle school years. According to Kohlberg, it is common for an individual to progress through stages where reasoning evolves from a basis of concern for personal physical needs and events to a concern which is increasingly other directed. Over several years of development, reasoning based on concern for self progresses to the simple need to "fit in", to concern for law and order, to concern for system of governance and social contract, to more general principles applicable to all mankind.

In junior high school, 45% of students reason at a level of "fitting in" 50% of the time. Those same students are capable of reasoning at a level where concern is for law and order (a necessary step towards reasoning based on systems of governance and social contract). Students who are provided opportunity to utilize their higher level concerns in a learning environment are found to use that higher level of concern on a more frequent basis outside of the classroom. This type of classroom experience gradually enhances the level of social maturity of students. Students progress to higher levels gradually as they increase the breadth of issues to which they give their attention. This broadening of interest to new issues does not occur if appropriate education is lacking. For example, many adults fail to apply mature skills to resolving significant science related public issues even though they demonstrate that they have those mature skills when the issues of concern are familiar. An accountant may express well reasoned and considered opinion in supporting a local school budget issue, but may reject out of hand and without considered thought the notion that there is need for public policy on the use of genetic engineering in medical research on fetal tissue. That issue may ultimately affect the accountant's personal life, and will certainly have significant impact on society. It is important that the accountant define a value, identify the issue, and make an informed decision on this issue. It is the middle school STS science teacher who has the best opportunity to develop the ability of all students to apply meta-cognitive skills to STS issues. It is during the middle school years that lasting notions of the relationship between self and society are formed, and it is during the later middle school years that lasting attitudes towards science are formed (3). Success in providing appropriate learning experiences depends upon the STS science education skills of teachers. The successful teacher understands the middle school student's perceptions of self and society, and is capable of creating different learning environments for different aged students.

Conclusion

Effective STS science education depends upon providing creative teachers with the opportunity to develop their own STS science programs. Resources necessary for the creation of such programs include knowledge of STS issues, understanding of the cognitive and meta-cognitive attributes of middle school students, competency in science education, and preparation to assume the role of change agent as schools adjust to the goals of STS science education.

Kohlberg's meta-cognitive model of age related stages in the development of moral reasoning provides an effective framework for understanding the development of concepts of self and society. Using this or similar models, middle school teachers may design learning environments which focus on development of values clarification, issue identification, and decision making skills, as well as development of science knowledge and skills. Such learning environments enhance competency in science for all students, and educate students who are socially responsible in science related issues.

Notes

1. Harms, N. & Yager, R. What Research Says to the Science Teacher, p. 7 - 8.

2. Penick, J. Chautauqua Notes, 3 #4, p. 1

3. James, R. & Smith, S. "Alienation of Students from Science in Grades 4 - 12",pp. 39 - 45, Science Education, 69(1), 1985.

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STS AND SOCIAL STUDIES: IMPLICATIONS FOR TEACHER EDUCATION

Charles S. White

Since the STS field and its advocacy of technological literacy are relatively new phenomena, any discussion of implications for teacher education is essentially a discussion of reforming the education of teachers. STS must therefore be seen as only one facet in a larger reform movement, reflected in such recent reports as Tomorrow's Teachers: A Report of the Holmes Group (Holmes Group, 1986) and A Nation Prepared: Teachers for the 21st Century (Carnegie Task Force, 1986). In exploring the preparation of teachers to integrate technology education in the social studies, one must do so within the context of a changing teacher education environment. The discussion here will be limited, however, to pre-service teacher education.

The Changing Nature of Teacher Education

Current Practice

The typical model for teacher education generally is a four-year undergraduate degree program with a major in education. This is true for both elementary and secondary pre-service education. Education majors take the required general education courses required by their university, in addition to other Arts and Science (A & S) courses designated by the school or department of education. The selection of the latter is based on state certification requirements for either elementary teachers or for secondary social studies teachers. A number of these courses may be courses designed especially for prospective teachers, but still considered A & S offerings. Finally, students take the required sequence of courses in education, including the methods course. During their undergraduate career, students engage in field experiences in schools, and their program of studies culminates in a half-semester or so student teaching experience. With B.A. in hand, a new teaching career begins.

Recommendations for Reform

The Holmes Group. What started as an informal forum of discussion among deans of a few schools of education grew to become the Holmes Group, dedicated to the reform of teacher education and of the teaching profession. Their report, Tomorrow's Teachers: A Report of the Holmes Group (Holmes Group, 1986), called for an end to the undergraduate education major and the extension of teacher education to a fifth year. This is necessary in order to achieve the goal of upgrading the basic liberal education of teachers. The Holmes Group also recommended differentiated staffing and teacher certification through alternative routes.

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The Carnegie Report. The Task Force on Teaching as a Profession of the Carnegie Forum on Education and the Economy produced its report after the Holmes Group issued its recommendations. A Nation Prepared: Teachers for the 21st Century (1986) shares many of the key recommendations of its predecessor. It supports the abolition of the undergraduate education major and the establishment of differentiated staffing. The Carnegie task force would replace the undergraduate major with a Master in Teaching degree very similar to the Master of Arts in Teaching degree invented by James Conant 50 years ago (Keppel, 1986).

Target: The Education of Teachers. What is particularly interesting in these reports is their focus not simply on teacher education; that is, the programs of study required by schools or departments of education. Rather, the reports target the education of teachers, a more inclusion idea that recognizes the contributions, and responsibilities, of both the schools of education and the colleges of arts and sciences in the preparation of teachers. The Holmes Group report in particular emphasizes the need for university-wide commitment to change (Imig, 1986). The distinction between teacher education and the education of teachers is useful as one considers the potential for pursuing STS goals in higher education.

A Fertile Environment for STS in the Education of Teachers

Reforming the Arts and Sciences

The major reform documents discussed above reflect a level of dissatisfaction with the quality of liberal arts education obtained by prospective teachers in universities. This feeling is part of a broader critique of general liberal arts education at the nation's colleges and universities. Recognizing some of the deficiencies illuminated by critics, universities across the country are taking a hard look at undergraduate general education and instituting changes.

In such an environment, the field of STS has opportunities in influence the shape of A & S reform, particularly as universities seek alternatives to traditional departmental structures. Hoffman (1987) has advanced an interesting alternative organization for A & S departments, including departments of environmental issues, futurism, recreation, moral issues, shrinking world, and technological issues. It may be that preservice social studies teachers will gain most of their STS knowledge from coursework in Arts and Sciences.

Reforming Social Studies Teacher Education

Methods course collaboration. Just as A & S departmental barriers may be softened, so may such barriers be reduced between subject-area methods courses in schools of education. Close collaboration between the science methods and social studies methods courses and instructors can serve to enhance the technological literacy of prospective teachers. This may entail coordinated syllabus development leading to a number of combined, team-taught class sessions, each demonstrating the interdisciplinary nature of STS issues and content.

The focus on social dilemmas and problems. The STS literature seems to speak in one voice about the need to develop K-12 STS curricula centered around social problems and decision making (Hoffman, 1987; Waks, 1987). This suggests that the social studies methods courses ought to demonstrate and allow students to practice strategies for teaching problem-solving and decision-making about social issues and problems deriving from technology.

For example, several class sessions and associated assignments might be devoted to the problem of pollution in the local community. The class would be guided in the application of problem-solving techniques to understand the complexity of the problem and to develop potential solutions. By engaging in problem solving themselves, future social studies teachers achieve a deeper understanding of the process they will teach their students. Moreover, these teachers enrich their understanding of the complex relationships among science, technology, and society that exist even at the local community level.

Educational technology in social studies teacher education. The point has been made that an overemphasis on computer literacy for teachers gets in the way of developing technological literacy, since both are often viewed as synonymous (Devon, 1987; Illich, 1987). When we engage preservice social studies teachers in using technology, then, we should not allow them to miss the larger context in which a particular technology has impact. This suggests that if distinct courses in technology are required, they should focus on technology and its social impact rather than just on computers and how to use them in the classroom. Technology education should also be integrated into the social studies methods course, as suggested above, but this cannot be limited to a single session on how to use a computer to teach social studies. Throughout the education of preservice social studies teachers, a broad conception of technology is imperative.

Conclusion

Changing both teacher education and the education of teachers will present severe challenges. There is the perennial problem of false integration; that is, for example, placing STS as a one-session topic on the social studies methods syllabus. Without careful curriculum design, content that is integrated has a tendency to be submerged. Moreover, changes in arts and science departments will be even more difficult to achieve, given the lengthy entrenchment in specialized turf that is characteristic of the university departmental structure. And not everyone is enthusiastic about the recommendations of reform reports.[1]

On the otherhand, unlike many reform recommendations, the success of STS at the university level has great potential to positively effect not only teacher education, but the education of teachers.

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TRAINING SCIENCE TEACHERS FOR STS

Gérard M. Fourez

Introduction

This communication presents curriculum content for the training of students majoring in science to enable them to be aware of Science, Technology and Society as issues. I will deal here with the training in Epistemology, in Sociology and History of Science, in Social Analysis, in Ideological and Value Analysis, in Ethics, in Technology Assessment, and in Philosophy and Sociology of Education. What will be presented is part of the training available to science students in the University of Namur (Belgium). This training is provided by a department called "Département de Philosophie de l'Homme de Science" which is a part of the Science Faculty (European universities are divided into Faculties) in charge of the nontechnical education of science students. What will be reported here is the amount of that nontechnical education relevant to STS issues. Some parts of this training will be more philosophical and abstract, while others, such as the ideological and value analysis of science textbooks, are definitely practical. The more philosophical education aspects help the students acquire the conceptual framework that enables them to see the connection between science, technology and society. The more practical training helps them to track how values, ideologies and societal biases are always involved in their teaching.

A First Theoretical Approach: Epistemology of Science

Most students and many teachers carry an image of science that stems from a positivistic philosophy. They believe that scientific practice begins with a faithful observation of nature and that, from this observation, it is possible to move on to some laws or theories which can be proved experimentally.

Such epistemology, typical of the XIXth century but still prevalent among many scientists, does not take into account the connection of science with human beings and human projects. Thus, it tends to represent science as a process ruled by the necessity of an absolute scientific rationality; consequently science is viewed as disconnected from any human, societal, and historical process. To be able to deal with STS issues, it is useful to employ an epistemological representation that shows the relationship between scientific methods and social processes.

The course of epistemology will show that scientific observation is never a process through which the scientist looks passively at nature to obtain data, but an activity through which a model of nature is constructed. The project underlying a specific scientific observation can be analyzed and connected to the paradigm of the scientific discipline in question. The human dimension of that social construction of reality which we call observation is to be emphasized.

Similarly, epistemological analysis will emphasize how that which we call empirical data always are filled with theoretical perspective so that it is impossible to actually separate the empirical from the theoretical. As theory obviously is a human construct, such a perspective, commonly held today by epistemologists, always brings to the fore the connection between empirical data in science and human projects. Empirical data, as every statistician knows very well, are never societally neutral: empirical "facts" are those interpretative models that people have decided, at least at that moment, not to contest.

This course of epistemology will then stress that scientific laws or models never "fall from the sky," but always are related to cultural and other societal features. As Duhem and Quine have shown, it is always possible to imagine an infinity of laws or models that fit a definite set of "observed data" and following Popper's philosophical model, theoretical "results" do not come from observation but from our previous representations, be they scientific, non-scientific, or even mythical. We always look at the world with some theoretical presupposition and it is only when that model does not satisfy us that we seek to create other models. Establishing new theories or models thus appear as a human creative activity, not implied by some logical necessity arising from data; this emphasizes again the connection between scientific practice and human history.

The ways through which scientists give up a theoretical model, again brings to the fore the connection between science and ordinary life. Practically no epistemologist still believes in the simplistic philosophical model that a scientist would give up a model when an experiment shows that it does not work. We know that it is always possible to save the model through ad hoc hypotheses, or by challenging the theoretical or practical devices involved in the experiments. It thus appears that giving up a theory does not stem from an abstract logic of scientific discovery but from decisions that stem from a daily life logic. And there, scientific practices have to be connected to economic, political, cultural, emotional, and career issues. Everybody knows that the most frequent reason to give up a scientific orientation is the lack of financial support for it. And financial support is connected with many other societal features. Here again, such an epistemological emphasis favors the connection between science and human history.

Finally, this epistemological perspective will stress what T.S. Kuhn has called "paradigms" or "disciplinary matrices," i.e. these societal presuppositions that are at the basis of a definite scientific discipline. Here again, epistemology, especially when it is connected to history and sociology, shows how science can be looked upon as some intellectual technology through which human communities succeed in mastering their environment. Such an approach helps connect science and technology.

A Second Theoretical Approach: Sociology and History of Science

Contemporary perspectives always unite epistemology, sociology and history of science. What I have reported of this epistemological approach shows that these three approaches have always been used together. It is impossible to understand epistemology without a socio-historical complement.

A socio-historical perspective will have to show to the students how scientific "paradigms" are always connected to a scientific community, which is itself in relation with economical, political and cultural features of a society. To realize this will compel the students to give up any attempt to conceptualize science as a process separate from society. Special emphasis should be given to understanding how these relationships shape the life of the scientific community. This will contribute to an awareness that the representation of the scientific community as a middle class group disconnected from any socio-economic-political pressures is inadequate.

Specific emphasis will also be given in this perspective, to the socio-epistemological analysis of laboratory life to stress how a laboratory is not only a scientific device but also a social device. The laboratory can be looked upon as a wonderful cultural invention through which we artifically protect scientific work from the intrusion of the world and society at large, so that in the laboratory, the environment responds to the experiment according to the presupposed framework of the paradigms. (To give an example, a laboratory is a place where the environment is so disposed that the friction forces will not prevent experimenting with laws structured according to the paradigm of mechanics.)

Socio-epistemological analysis will also show how modern scientific knowledge is always connected to what we can do. Through scientific law we intend to master our world, first in the laboratory, then in society at large. The connection between science and mastering nature will thus be emphasized, compelling us to reflect at the connection between knowledge and power. Thus, the distinction between science and technology will have to be reconsidered because science will appear as intellectual technology seeking to master the universe as well as material technology.

Socio-historical approaches will then help the students to see that it is never adequate to separate science, technology and society, even if, for some purpose, a distinction can be helpful.

A Third Theoretical Approach: Social Analysis and Philosophy of Education

Students at the University of Namur (Belgium) who want to be prepared for science teaching, have to take a course that analyzes how education and the school system connect to society at large. The aim of the course is to become aware that teaching in school is not only a profession through which a person teaches other persons, but is part of a wider societal context.

In such a course, people are first confronted with the fact that teaching means "to have a project," and to want to influence the students. This goes against the common prejudice that a scientific education can be value free because it seeks to deal only with scientific data. The course analyzes how, in the teaching project, there are many interactions between the projects of the teachers, those of the parents, those of the school, and those of social groups and lobbies that are able to influence education. Analysis examines how students can become autonomous and master their own project in the middle of all this. Science teaching is thus confronted with the issue of human manipulation, and all the psychological and ethical issues involved.

Schools are then looked upon as institutions that are operating in a given society. Which are their open and hidden functions? How do they relate to the industrial society? How do they evolve with that society? What is the societal meaning of compulsory education?

Schools are also considered as a social field where people and social classes do interact each with its own strategy. It is analyzed how the access to knowledge can be looked upon as a way to get access to social power, either through better jobs, or otherwise. How specifically being scientifically and technologically literate has become a way to get a place in society. The future teacher is thus made aware that school never can be looked upon as only a benevolent way of giving knowledge, but as an institution where social struggle is always present. It is present in the classroom where individuals follow their own social strategy, but it is mainly present in the institutions through which social groups try to preserve their privileges or to acquire them.

This awareness of education as a socio-political field aims at helping the future teacher become aware that teaching never can be disconnected from social objectives. This is particularly clear if one wonders which are the societal objectives of science teaching. The goal is, through this educational unit, to show how deciding on curricula in science is not first a scientific action, but rather a socio-political one. Scientists have to be aware that science is never taught to children solely for the sake of science, but because some people endowed with the requisite power and prerogatives have thought that -- according to their own representation of a good and just society, or according to their interests -- such or such scientific items have to be taught to such or such type of student.

Some other topics related to the connection between education and society are also studied in the course, with the view of making the future teacher aware that education is always " a place" where decisions are taken, and that it is never free from values and socio-political goals.

A First Practical Approach: Social Analysis and Technology Assessment

In order for students to better situate themselves in the social field that is science teaching, they need some practice in social analysis and technology assessment.

To do so, they will receive tools for analyzing. And, in specific cases, they will learn how to situate the societal conditioning of human action. They will be trained to recognize the economical factors in decision making processes, and then the political factors, the cultural ones, the emotional ones, etc.

This kind of analysis will be applied, in some seminars, to decision making in scientific research and science management. It will be considered how these factors influence research strategies.

Technological assessment will also be part of the training. Choosing some historical cases, they will study how technological decisions have structured social as well as the physical environment. Through specific analysis it will be shown that technology (intellectual as well as material technology) cannot solely be viewed as a tool or a device to get some results, but that it always carries some social organization. For example, introducing a computer into a company does not only mean bringing in a new tool, it also implies changing the social organization of that company. Or deciding on a technology to produce energy for a country is also deciding about some organization (and generally it induces some specific requirements for police forces and security in that country).

A Second Practical Approach: Value and Ideological Analysis

Finally, students majoring in science have to be aware of the concrete ways through which values and ideologies are carried in science classes. Experience has shown us that this never happens only through theoretical reasoning, but only when confronted with textbooks or videos of science classes. But, before getting to that confrontation, several intellectual and psychological resistances have to be overcome.

First, it is important that future teachers do not enter into a guilt trip when they realize that values and ideologies are necesssarily part of their teaching. It is not easy because in Belgium most of the science teachers are still convinced that a good science course is value-free, and that if it carries values, that is "bad." Thus, it matters that the future teachers be aware that they are not asked to have classes that would be ideologically "clean," but that there can be some ethical reason not to want any kind of ideological biases. We often use the comparison of bacterias in the intestine: if there were no bacterias there, we would be in very bad health, but not every kind of bacteria is welcome. It is the same with ideologies and values in science teaching.

Second, it is also important to realize that ideologies in science classes come up when most of the pupils in the class and most of the teachers are off guard. If it happens to be a class about religion, ethics, or social sciences, pupils most of the time are quite critical and well decided not to accept blindly anything that is taught to them. But in science classes, they are generally ready to accept as truth everything they are told. That is why some say that science is taught today in a similar way as religion was taught a couple of centuries ago: presenting truths to behold.

Third, future teachers have to weigh the consequences of the fact that a science curriculum is not organized primarily around an absolute scientific rationality, but around a societal project (what do we want to teach these young people), obviously taking into account the limits of scientific knowledge on the one hand, the learning abilities of the pupils, economic data, and the amount of flexibility of the teachers on the other. In view of that, analysis of textbook introductions is helpful. If often shows how easily the societal projects behind a curriculum are concealed.

This kind of seminar also examines how, in the content of a science class, world views, ideologies, and values are carried to the pupils. To do this, a specific tool has been developed: rewriting textbook sections. What is done is to examine a section of a textbook, to see if it is be possible to carry a similar scientific content with other ideologies, values or worldviews.

For example, in a given physics textbook, in a section relating to electricity, it is written: "Through the following experiments, we will prove that the distinction between conducting and isolating material is a fact." A rewritten possibility would be: "Through the following experiment, we will see that it can sometimes be helpful for people to distinguish between conducting and isolating material." Then we analyze what kind of mental framework is induced by each text.

As a second example, let us consider the title of a section in a biology textbook which reads: "Learn how to observe." Two different versions of that title were presented: "learn how to observe as scientists do," and "Learn the observation techniques of biologists in the field." Each of these titles fits the section that followed in the textbook, but the mental structurations coming from each differs.

As a third example, an introduction to a textbook states that it "contains too much material for the class of that level, but that the teacher will **immediately** (bold characters are mine) see what is fitting for his (her) class." A rewritten text could mention that the textbook "contains too much material for the class of that level, but that the teacher will, after careful analysis of the situation have to decide what he (she) believes fitting for his (her) class." The first text induces a tendency toward technocracy (believing that knowledge gives a solution to practical problems, without any mediating social analysis and negotiation) while a second emphasizes that a human decision is always needed to reach a solution to a problem.

Many other and more elaborate examples could be expanded here, using texts speaking of scientific methods, the history of science, the applications of science, or even the very content of a discipline. I have done that in other publications. It is important to know that future students have to be aware that values and ideologies are carried much beyond the topics that have become the apple pie of much STS training like transmission of life, ecology, abortion, euthanasia, arms race, pollution, etc. The most significant structuration of the mentalities often happens when teachers and pupils believe they are the most neutral with respect to values.

The goal is not to tell future teachers that there is a good way of transmitting values, or good values to be transmitted, but to make them aware that they do it. Then it is hoped that they will be able to behave in a responsible way like teachers of literature who generally believe that it is to be deontologically responsible to avoid too much biases in the choice of authors for their classes.

Conclusion

I have expressed the main trends of STS training as it has been developed at the University of Namur (Belgium) by the "Département de Philosophie de l'Homme de

Science" ("Department of the Philosophy of Scientists," founded in 1970). Obviously, some parts of the training are working better than others. But we believe, that on the whole, it contributes to a change in the mentality of science teachers. In Belgium in the past, science and mathematics were believed to be a complement of an education that was carried for the most part, in other classes (like French Literature, Latin, Greek, Foreign Languages, History, Geography, Social Sciences, Ethics, Religion, etc.). Now people believe more and more that science and mathematics classes are at the very core of a global education. But to prepare the teachers to that effect and to give them the practical training that enables them to be true global educators, we still have a lot to do -- especially as many of the students majoring in science still hope to enter into a neutral field, and so to escape from the societal conditions that are prevalent in other professions.

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TECHNOLOGY PREPARES TEACHERS IN STS

Minaruth Galey and E. Joseph Piel

The need for secondary school students to study science, technology and society (STS) is growing as rapidly as our technologies are. The unpredicted, unexpected impacts of technologies, for example on our environment, are accumulating to levels that sometimes appear to be approaching the point of no recovery. The positive aspects of technology are often overlooked because the problems are so great.

Recognition of those problems is growing. It is clear that those who are secondary school students today must be able, as adult citizens, to increase the efforts to stop, slow and/or clean up the negative effects of technologies while accepting the positive effects.

One effort to teach students the subject of STS is called "You, Me and Technology" (YMT). The purpose of that project was to help secondary school students to be effective citizens in this complex technological society. To meet that purpose, a curriculum of STS was written for YMT by Leon Trilling of MIT with the authors. There were no teachers prepared to teach the whole STS curriculum, but certainly it supported the teaching of science, mathematics, technology, social studies, English/communications, and vocational education.

The decision to implement the curriculum using the technology of television was primarily related to the obstacle of preparing a great number of teachers in the subject matter of STS. Teachers and students learn together from each program. Another advantage of television is that a large proportion of teachers are familiar with the use of the medium for instruction. Recognizing the TV lesson as a part of instruction, teachers introduce the program to guide the students' viewing to meet the learning objectives. After the program, teachers conduct activities to clarify and reinforce the new knowledge.

Television also assists learning by holding the attention of the viewers. Television cameras can go to any location to show an actual event. Seeing examples of abstract ideas makes the abstract concrete to the students.

The programs were designed to support teachers in teaching a course in STS and also support teachers in infusing some STS topics into their subject areas. The programs were limited to 20 minutes to permit both introductory and follow-up activities in the common 45-50 minute class period.

Each of the 12 programs in the YMT instructional television series develops one of the 12 topics of the YMT curriculum. The programs may be viewed singly or in any combination and sequence. Different formals are used in the programs. A few have a host; several are documentaries or magazine; and some are dramatized. In addition to the design of the programs, the needs of the teachers are addressed in the YMT Teachers' Guide. It has the standard format for each lesson: program summary, objectives, suggested introductory and follow-up activities. Short follow-up activities are suggested in five categories: Science and Technology, Mathematics, Social Studies, English/Communications, and Vocational Education. The two integrated activities for each program require more than one class period. Because there are very few instructional materials in STS, three transparency masters for each lesson are in the Guide. Additional resources for both students and teachers are listed also.

A student workbook is being developed for use in Fall, 1988. It will include individual and group activities for each of the programs.

Because STS is both new and multidisciplinary, teachers have expressed a need for workshops or some additional demonstrations of effective activities. The staff of YMT developed a thirteenth program directed to the teachers.

An additional need for Program 13 developed as the Agency for Instructional Technology (AIT) began to disseminate the YMT materials across the nation. AIT schedules a satellite broadcast so that prospective buyers can copy all of the programs for preview. If the buyers like the series, they keep the copies; if not, they erase the copies. As efficient as this delivery system is, it produces the difficulty of no one on-site to demonstrate to the teachers how the programs can be used effectively in their subject areas.

The junior author is an experienced classroom teacher and principal as well as the YMT content specialist. He served as host educator. Scenes from different programs are shown. After each scene, the host describes at least two activities for different subject areas. The thirteenth program, "Teaching with You, Me and Technology" is proving very successful. The program is furnished at no cost to those using the YMT series.

YMT is effectively meeting the special needs of teachers as they expand their efforts in assisting their students to prepare successfully for their lives as citizens in this technological society.

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PREPARING STS TEACHERS IN NEW ENGLAND

Lloyd H. Barrow

The purpose of this study was to gather demographic data about the course content of secondary science methods courses taught at New England higher education institutions. This study was a component of a larger study that gathered demographic data about New England secondary science methods faculty (Barrow, in print). The larger study utilized a 79 item questionnaire which was a modification of Barrow's survey instrument (1984). Surveys were mailed to identified secondary science methods faculty at the 56 New England teacher education institutions. Two follow-up letters were utilized to non-respondents. A total of 25 surveys were returned from the 43 available faculty, resulting in a 58.1% return rate. Procedures for this study are reported elsewhere (Barrow, in print).

Results

Overall, the respondents were principally male (88%), senior faculty (72%), tenured (68%), full-time employees (82%) and 7-12 years teaching experience prior to college teaching (80%). Barrow (in print) provides more complete demographic information about respondents.

The ranking for the 28 content topics of secondary science methods classes are reported in Barrow (in print). The six highest priorities were: nature of science, inquiry teaching, science processes, classroom management for science, safety concerns, and laboratory teaching strategies. While the six topics with the lowest priority were: concept mapping, Vee mapping, energy education, marine education, content reading strategies, and science fairs.

Regarding science, technology and society (STS) concerns, less than 50% of the responding faculty are providing at least one class for discussion. Overall, at least 67% of the respondents are providing an awareness of ST in their secondary science methods course, except for values clarification (Table I).

Discussion

Overall, the respondents gave a low priority regarding STS (ranked 18 of the 28 topics). In addition, they gave utilization of computers (ranked 21) a low priority. It can be surmised that the respondents have chosen to ignore the National Science Board's recommendations (1983) that there be a course with application of science to society focus. Yager and Lunetta (1984) recommendations for secondary science methods instruction are either being ignored or were unaware of by the responding science methods faculty.

Even though STS is not recognized as a goal for science education by all science educators (Good, Renner, Lawson, and Herron, 1984), future secondary science teachers should be aware of the evolution of science education goals. NSTA's position paper on

Table I

Strategies utilized by New England secondary science methods to prepare future secondary teachers to deal with STS topics

	Indepth Presentation (1 class or more)		Awareness Level (1 class)		Not Included		No Response	
	n	%	n	%	n	%	n	%
Difference between science and technology	7	28	11	44	5	20	2	8
Impact of science & technology upon society	12	48	8	32	3	12	2	8
How technology influences our lives	10	40	9	36	3	12	3	12
Ethical considerations	8	32	11	44	2	8	4	16
Values clarification	4	16	8	32	2	8	11	44

STS (1982) recommended that at least 20% of the science instructional time be devoted to STS topics. It appears questionable that responding secondary science methods faculty are modeling this goal with their preservice teacher.

In response to an open-ended question, respondents identified a diverse group of STS topics they utilize in their secondary science methods class. Topics mentioned three or more times were: genetic engineering, energy, world hunger and population, creationism vs. evolution, and nutrition and organic foods. These STS topics are deemed appropriate according to Project Synthesis (Harns and Yager, 1981), Roy (1985), and Yager (1985).

If preservice students of New England are not receiving a STS orientation from their secondary science methods faculty, are they receiving this perspective from their college science instructors? Probably not, since most college scientists are preparing future scientists rather than future science teachers. Therefore, it is imperative that secondary science methods faculty provide indepth instructional time on STS. If preservice STS is inferior or lacking, will science teachers be able to prepare their students for the twenty-first century?

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FORMAL COURSES IN STS FOR ADULTS: RATIONALE AND REALITY

Barbara Beigun Kaplan

With the growing sophistication of STS as a coherent discipline arises the need to create sound instructional programs tailored to a variety of different audiences. Much effort has been made to address the need for scientific literacy in the K-12 population. Curricular reform in this sector, though slow, is being achieved, with substantial encouragement from the National Science Foundation.

Impressive inroads have also been made in the development of organized STS programs for full-time undergraduates and graduate students in the nation's colleges and universities. There now exist nearly 100 full-fledged STS programs and hundreds of individual courses or sets of courses on American college campuses and in foreign universities as well.

Certainly it is fitting that the thrust of our efforts be directed toward the youth who will inherit this rapidly changing techological world. But what of those who have already finished their initial formal education? What of the working adults in the community, who in many cases are parents of children who are now relatively comfortable with computers and high technology--those same children who are the primary targets of STS-related curriculum reform? By failing to address the educational needs of these adults with the same intensity with which we aim to enlighten their children, are we not, in fact, creating a more pronounced generation gap? And are we not, by this omission, neglecting precisely those people who both could benefit most immediately from planned, organized STS-related education?

Statistical studies of adult interest in science and technology show that this segment of the population is often very concerned with such topics while remaining relatively ignorant of basic scientific and technological concepts.1 The deep-seated concerns and fears of adults regarding our present technology have also been documented. It is, of course, this sector of the population which feels the impact of technology most directly--whether in the workplace or in the community. How are these adults to obtain the depth of perspective necessary to participate effectively NOW in political decision-making regarding technological issues?

Too often, it is assumed that the media alone can provide "literacy" to these adults outside the formal school system. But is casual exposure to even the most well-produced public science documentaries, such as "NOVA," sufficient to meet the extensive informational needs of this population? Even where opportunities exist for dialogue and public education on specific issues (for example, a local debate on the siting of a sewage treatment plant), is such piecemeal "consciousness raising" sufficient to achieve that broad understanding which is the goal of our formal STS instructional programs for children?

If the need for more extensive public education is to be addressed, one very effective strategy would be to utilize the superstructure of already existing adult education programs. STS educators and community leaders can and should actively encourage the development of credit or non-credit courses and workshops for adults aimed at promoting technological literacy and investigating the interrelations of science, technology, and society. Adult education is, after all, the most rapidly growing sector of higher education at the present time.2 Enrollment of adult part-time students is increasing yearly, and the concept of "lifelong learning" is making considerable headway among members of the adult population. New methods of course delivery (including interactive, computer-based instruction and telecourses) now provide viable pedagogical options for adults, regardless of where they live or whatever scheduling constraints they may have.

If little progress has been made on this front as yet, it is not so much due to our neglect of adults as to some very real built-in limitations of many adult education programs, particularly those associated with colleges and universities. Financial constraints militate against the establishment of many full-fledged curricula, particularly in disciplines not predominantly skills-based. Adult education programs offered through colleges and universities are often largely self-supporting, and given the stiff competition these programs face from proprietary training schools run by industry, the bulk of their resources must be directed to the development of career enhancement courses. In addition, adult education programs primarily rely on part-time faculty, hired on a temporary contractual basis. These faculty often hold full-time jobs outside the educational system and have little time to devote either to amplification of existing courses or development of new ones.

Given these limitations, is there still sufficient "leeway" for the establishment of STS-related courses in adult education programs? The answer is yes, on several grounds. Accreditation concerns and the demands of formal degree requirements ensure that basic general education courses will always be offered. College affiliation is often perceived as a "plus" by potential adult students who, in fact, like to see some purely intellectual courses among the catalog offerings, for this gives added credibility to the program as a whole. Recent discussions among college educators concerning ways to evaluate how well students have learned to integrate the knowledge they receive have prompted some administrators to consider offering interdisciplinary or "capstone" courses, projects, or seminars, not only for regular undergraduate programs but in adult education programs too.

It is in conjunction with these efforts toward integrative knowledge that one might best promote STS-related instruction for adults. Interdisciplinary by nature, contemporary in scope, and embodying content conducive to testing student skills in critical thinking and problem solving, STS courses can be developed specifically to enhance general degree requirements for adult education programs, perhaps not extensively, but nonetheless, usefully.

If such courses could be developed, how should they be designed? In general, an introductory STS course for adults should incorporate many of the same goals as those proposed by the Working Party of the S- STS Project for a "model one-year STS introductory course."3 However, certain characteristics peculiar to the adult student must be considered. The most obvious is that adults prefer one-semester to year-long courses, primarily because of schedule limitations. Also, adult students not only have much more limited time, but also limited funds and often limited energy to devote to their classes. Translated, this means that courses in STS developed specifically for adults often cannot have some of the add-ons which are characteristic of STS courses in regular college programs. Realistically, library research time is limited, field trips and labs are infeasible, and large-group projects are often impractical. However, to balance these constraints, it must be noted that there are positive characteristics which make developing courses for adults rewarding. Readiness to learn is often higher than that of typical 18-to-21-year-olds in traditional college programs.4 Thus, the instructor can expect a high level of student motivation and participation. Moreover, adults bring to their studies a varied and rich mix of life experiences. This enhances their comprehension and interpretation of the material presented.

A variety of course formats are possible. The most typical is the traditional classroom lecture and/or discussion approach. Creative introductory STS courses could be developed in this format and enhanced by audiovisuals, simulations, case study comparisons, etc. Although enrollments may not be as high as for career enhancement and skills courses, such an STS course may find a comfortable "niche" by fulfilling a general education requirement for degree programs or by providing problem-solving content for a "capstone" course.

STS-oriented material may also be infused into existing courses. For example, a basic computer course could include some units which address value issues and social impacts associated with that technology. A course in technological management might discuss the ramifications of research and development efforts in the business sector. This integration of STS and skills-based courses is in itself a commendable goal, although such an approach alone would never provide the necessary broad-based perspective which those of us promoting STS desire to impart. Nonetheless, such a "piecemeal" attempt is preferable to no attempt at all.

A third set of possibilities involves the establishment of STS- oriented courses in an independent study or distance delivery format. Such courses have the advantages of flexibility and transportability, making them ideal for students with busy schedules. They can be structured in 6 or even 9 credit modules, which would allow the incorporation of more and diverse reading assignments--a distinct plus for courses interdisciplinary in focus. They can utiize supplemental materials (for example, through a lending library of videocassette tapes or audio tapes). They can be tied to museum exhibits and demonstrations, public television series, or cable telecommunications. They can even be fully computer-based.

Course development costs for this mode of delivery can be high, although reusability permits a payback in the long run. There is also the possibility of engaging in consortium arrangments for the sharing of materials. The lack of classroom dialogue can be a drawback (since adults prefer a classroom experience which is participatory), but this can be countered in a number of ways. One way is the semi-independent study option, in which tutorials are held weekly (with attendance optional) to allow students and facilitators to discuss an assigned topic. No new information is imparted during these tutorials, since not all students attend. However, these tutorials are beneficial for students who wish to engage in dialogue with other students and receive feedback on their understanding of points made in their independent reading. Other options are to set up teleconferences, use computer messaging, or simply rely on regular telephone or mail communication to increase student-instructor interaction.

As an example of what might be done to incorporate STS-related courses into an adult education program, one can examine the situation at my home institution, the University of Maryland University College. There, in the semi-independent study program known as Open University, two courses have been created which relate to STS. Course development was coordinated by the Center for Instructional Development and Evaluation, and was accomplished by a team consisting of a content expert, curriculum specialist, and an instructional designer.

One course in the technological management curriculum, entitled "Science and Society," initially had been developed to address issues of science policy for students in a business-related discipline. A decision was made in 1985 to revise the course to permit granting partial science credit to students taking this course. Retaining the focus on the political and economic ramifications of science and technology, the content of this course was expanded to provide basic scientific and technological literacy in key areas and to discuss the social and ethical impacts of specific technologies.

In 1987, it was decided to develop a new course for the humanities curriculum on the subject of "Technology and the Individual." The intended focus was the impact of modern technologies upon the individual's perceptions of the world. Although the intent was specifically to enhance the humanities curriculum, the project provided an opportunity to design a course fully complementary to the earlier one, drawing on a totally different literature--the classics, science fiction, essays, historical interpretation, and drama.

As a result of these efforts, there now exist two courses at University College which present to students many of the concepts basic to STS. Although developed for two separate curricula, the two courses are complementary, containing much of the same material as is found in the core courses of formal STS programs. Even if no further efforts are made to expand the STS focus within the University College programs, these two existing courses will still serve as viable, stand-alone efforts to impart basic STS-related ideas to adult students in a formal pedagogical manner.

Courses of this type can and should be made available in other adult education programs. It is clear that there is presently little support for the idea of developing full-fledged STS curricula for adults. But incorporating courses such as the two described above into existing curricula could still perform the useful public service of imparting to adults, in a formal, structured way, that basic education regarding the issues and facts about science and technology which is so crucial to the creation of an informed citizenry, and to which adults, no less than children, are entitled.

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4. Malcolm Knowles, The Adult Learner: A Neglected Species, 2nd edition, Gulf Publishing Co., Houston, TX (1978).

5. Ibid.

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SOCIO-TECHNOLOGICAL PROBLEMS AND ISSUES: AN ADULT EDUCATION GRADUATE COURSE

Thomas T. Liao

Introduction

11/3/87:	Citizen activist speaks about Proposition 2 (proposal to protect Suffolk County's ground water) that will appear on the ballot on election day.
11/17/87:	Research physicist reports on his trip to Antarctica to study the Ozone hole problem.
12/8/87:	AIDS education expert discusses the problem and her program for limiting the spread of the disease.
12/15/87:	Suffolk County legislator explains the rationale and content of a new uniform packaging bill.

What do the above four events have in common? They are all visits by guest speakers to an adult education course that deals with socio-technological problems and issues. Providing students with meaningful and up-to-date examples of contemporary problems and issues is one of the unique features of this course. But why do adult students need this type of course?

Adults make many occupation-related and personal technology-based decisions that require understanding of the technology and science and math concepts that underlie S-T-S problems. These decisions also require understanding of the decision-making process and how they are affected by the accompanying societal, economic, and environmental impacts.

At SUNY/Stony Brook, the Department of Technology and Society (DTS) offers technological literacy courses for both undergraduate and graduate students. This paper will focus on "CEN 580: Socio-Technological Problems and Issues," a course designed for adult education graduate students. The characteristics of target audiences, the design criteria, the description of the specific curriculum materials and student activities/projects, and the evaluation system are some of the aspects of the course that will be discussed in this paper.

Characteristics and Educational Background of Students

In order to specify design criteria to guide the development of the curriculum, the characteristics, capabilities, and limitations of the students must be determined. First, an estimate of the background of potential students is carried out. Then a student questionnaire is used on the first class session to verify and fine tune the information about the students in the course.

The course is taken by two groups of graduate students. In our department's MS in Technological Systems Management (MS/TSM), this course serves as an introductory course that is required of about half of the students. At SUNY/Stony Brook, the School for Continuing Education (CED) offers an MA in Liberal Studies (MA/SL), that requires a foundation course in science or applied science. CEN 580 has been modified to qualify it as an MA/SL foundation course.

In general, the MS/TSM graduate students have more science and technology background and some of them are working for technology-based companies. Most of the MA/LS students are pre-college school teachers and some of them do not have much prior knowledge of science and technology. Thus, the design of a survey, introductory STS course for this diverse audience has been a real challenge.

In the Fall 1987 semester, fifty-four students were enrolled in this course. Their ages ranged from 23 to 55. At the first class meeting, students filled out a questionnaire which asked for the following information:

(1) Which graduate program are you in? MS/TSM ____ MA/LS ____ Other ____
(2) Are you a full-time graduate student? Yes ____ No ____
(3) If no, what is your occupation? ____________________
(4) If you are a teacher, indicate the subject(s) and grade(s) that you teach.________ ____________________
(5) Why are you taking this course? Required course ____ CED Foundation course ____ Other reason ____________________
(6) What was your undergraduate major? ____________________
(7) What was your last science course? ____________________
(8) What was your last math course? ____________________
(9) How much working experience do you have with microcomputers? High 5 4 3 2 1 Low
(10) Which microcomputer have you used the most? Apple IIe C ____ IBM/PC ____ C64/128 ____ Apple Macintosh ____ Other? __________

Over half of the students (36) were MA/LS students, and 11 were MS/TSM students. Most of the students (45) were part-time graduate students and 28 of this group were school teachers. About 60% of the students (33) were taking the course because it was a CED foundation course.

Besides the numerical information, the questionnaire also verified the fact that this was a group of graduate students with very diverse backgrounds. The school teachers (28) primarily taught at the secondary school level, but were every evenly divided in terms of subject matter. About half of the class had limited backgrounds in both math and science. For example, 15 students indicated that the last math course they took was in high school.

About two-thirds of the students indicated that they had a working knowledge of microcomputers. The most familiar machine was the IBM/PC (19), with the Apple IIe series being second (12), and the C64/128 (6), and Macintosh (6) microcomputers were tied for third.

Design Criteria

In order to guide the development of a curriculum that would provide an introductory experience in technological literacy to such a diverse audience, the following set of design criteria were specified:

(1) All instruction must start with concrete examples that have relevance for most of the students.

(2) The underlying math and science concepts of the socio-technological problems must be reviewed or taught when they are discussed.

(3) Assignments must be open-ended and provide opportunities for students to relate the course materials to their work and home environments.

(4) Students must have individualized instruction in the microcomputer laboratory.

(5) Students must have the opportunity to discuss the weekly assignments and term project on an individual basis.

(6) Lectures must be followed by small group discussions.

(7) To provide a broader range of topics and expertise, guest speakers must be used periodically.

Overview of Curriculum

Course Description: The systematic study of a series of case studies that relate to current socio-technological problems and issues. Problem areas include auto safety, water and energy resources, population dynamics, electronic funds transfer, and telecommunications. Emphasis will be placed on the assessment of emerging technological systems and the science and mathematics that underlie these systems.

Auto Safety: Sample Topic and Assignment: The auto safety problem was used as the first topic and was used to introduce an approach to the study of socio-technological problems that posed the following questions:

To examine a series of socio-technological problems and issues in terms of

A. Is is really a problem?
B. What caused the problem?
C. What are the alternative solutions?
    1) educational
    2) legislative and legal
    3) technological (applied science)
D. What are the viable options?
E. Will any individual option solve the problem?
F. Will any of the options cause new problems (societal impacts)?
G. How do we select an optimum solution?
    1) modeling (applied mathematics)
    2) decision-making among trade-offs

Besides the lecture and discussion of the auto safety problem in class, students were also provided with an Auto Safety monograph (part of a set of readings that were selected for the course) that was written by the DTS faculty. Assignment I asked students to use the above information as a foundation to research and write about one recent approach to solving part of the auto safety problem.

Computer Simulation and Modeling

In conjunction with the study of "Energy Supply and Demand" problems and "Population Dynamics," two computer modeling laboratory activities were used in the course. Since some of the students had limited experience with microcomputers, the easier-to-use Apple Macintosh machines were used. A second reason for selecting this machine was the availability of a new simulation software package called STELLA, that only runs on the Macintosh.

STELLA was used to involve students in the study of population models. Specifically, a model of China's population dynamics was developed to study the impact of the one-child policy. More importantly, what will happen if this policy is relaxed, as is currently happening.

An electrical energy use inventory model was also developed using a spreadsheet software called MacPlan. Students collected data about the number, wattage, and time of usage of electric lights and appliances in their homes. A model was developed using this data to determine energy used per month and the cost of running each appliance. The total energy used and cost was also determined and compared with the information from an electric bill.

The experience in the laboratory was also used to involve students in an ergonomic or human factors analysis of the Macintosh human-machine interface system. The evaluation of the WIMP (Window, Icon, Mouse, Pull-Down Menu) system provided a concrete example of the importance of matching machines to people. Ergonomic considerations was one of the reoccurring themes of this course.

Instructional Objectives and Evaluation Instruments

As indicated in the course overview and the auto safety module, the primary delivery system for the study of STS problems and related concepts was via contemporary socio-technological problems and issues. Specifically, the course was designed to help students master four major instructional objectives. Upon completion of the course, students should be able to:

(1) analyze the causes of socio-technological problems and issues.

(2) evaluate and compare solutions (technological fixes, legal procedures, and educational techniques) to socio-technological problems.

(3) comprehend and apply the underlying science and mathematics concepts of socio-technological problems and issues.

(4) comprehend and apply technology assessment techniques and methods (e.g. technological forecasting, impact analysis, and risk assessment).

Evaluation of student achievement of the above objectives was carried via two examinations, four bi-weekly mini-projects and a term project. One of the mini-projects dealing with solutions to the auto safety problems has already been discussed. The other three mini-projects are related to water resources, domestic use of electrical energy and population dynamics.

An excellent method of determining what students learn in a course is to review the questions from an examination. For example, the following four questions for the second examination are provided as samples of how instructional objective #4 was evaluated:

(1) The Delphi Technique is a method that is often used in technological forecasting. Describe how information is obtained and processed to provide an estimate of the future of technological developments.

(2) Peter Drucker is a critic of Technology Assessment (TA). Describe why he is against TAs and what he recommends as an alternative to TA.

(3) Describe two types of actions (responses) that can follow the assessment of a specific type of technological system.

(4) A decision or relevance tree is often used to depict policy alternatives. Is this normative forecasting technique more useful in a Technology-Initiated Assessment (TIA) or a Problem-Initiated Assessment (PIA)? Why?

Besides performance on two examinations and four mini-projects, students also demonstrated their understanding of concepts and techniques by carrying out a term project. In order to provide a meaningful term project and paper for all members of such a diverse group of graduate students, three alternatives were provided as follows:

(1) Limited Technology Assessment: Study a socio-technological problem that was not discussed in detail in the course. The emphasis of the paper can be from one or two perspectives: (a) Problem Initiated Assessment; (b) Technology Initiated Assessment.

(2) Critique of a Technology and Society book. Ten of the readings in "Technology and the Future," edited by A.H. Teich, are excerpts from other books. The acknowledgements section provides specific information about these books. For example, a term paper could be based on The Third Wave by Alvin Toffler. A comparison could also be made with Toffler's earlier book Future Shock.

(3) Infusing science, technology, and society topics in courses of study. Describe and provide specific examples of how the concepts, points of view, and examples used in this course can be integrated into a course that you teach.

Concluding Comments

Last summer while planning this course, the major pedagogical problem that needed to be addressed was the diverse audience that had to be served. Although a difficult problem, the interest and willingness of the adult students to devote additional effort made the course work. In fact, the variety of academic and professional backgrounds made the course more relevant and meaningful.

Class discussions were often enhanced by students' comments and examples. Thus, students learned from each other as well as from the lectures, reading materials, and assignments. The total learning experience for myself and my students was certainly more than the sum of our individual contributions. In Buckminster Fuller's terminology, synergistic learning was certainly an additional feature of this course.

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THE USE OF DRAMA IN TEACHING ABOUT SCIENCE AND TECHNOLOGY

Wytze Brouwer

Introduction

My interest in science-technology-society (STS) issues has long been stimulated by public concern about environmental issues, by the use of sophisticated technology for military purposes and by the concern whether or not the human race is sufficiently mature to protect itself from the potentially destructive effects of some technologies. A number of influential reports(1,2) issued during the early 1980's emphasized the need to educate students in such issues so that citizens in our democratic societies might gain a better understanding of such problems and become able to make more informed decisions about STS issues. This concern about the interaction between science, technology and society triggered my memory about a number of plays by Ibsen, Shaw and others that had treated STS issues from a different perspective and by way of a different medium than, we as science educators, were used to employing in our classrooms. In fact some research showed that there is, in fact, a long tradition of the portrayal of science and society issues in poetry and drama, and that dramatists, especially after World War II, portrayed such issues decades before most science educators and scientists became concerned. In this paper, I present an overview of a few of the plays that I and my students have found especially interesting or effective in presenting STS issues, and reflect briefly on the images of science and the courses of action open to scientists in potential STS conflict situations.

The paper will focus primarily on three STS-related themes:

(1) The image of science and scientists in the society portrayed,
(2) The impact of science and technology upon that society,
(3) The different courses of action open to the scientists portrayed in the plays.

The plays selected form, of course, only a small selection of the plays written on the theme of the interaction of science and society.

The Plays

Thomas Shadwell's The Virtuoso(3) was probably one of the first plays that featured a scientist, a relative newcomer to the social scene, as a central character. When Shadwell wrote the play, the "new method of science" introduced in Francis Bacon's Novum Organum was only 50 years old, and scientists like Robert Boyle, Isaac Newton, Robert Hooke, and Christopher Wren were only beginning to establish a reputation in Great Britain. In his central character, Sir Nicholas Gimcrack, Shadwell collects all the personal and scientific oddities that he sees in the early members of the scientific community. In the play, one sees Sir Nicholas engaged in theoretical swimming by the imitation of frogs, in studying the response of spiders to music, practicing artificial respiration on animals, studying the results of blood transfusions from sheep to humans, reading his Geneva bible by the light of a rotting sirloin of beef, and similar outlandish experiments. If it were not for the review of Marjorie Nicholson(4), who traced each of these experiments to actual papers in the Philosophical Transactions or to the minutes of the Royal Society, one would have been tempted to dismiss Shadwell's play as a rather poorly written, exaggerated picture of early British Science. In fact, the apparent randomness of the research topics pursued by these early scientists can be used as an illustration of Thomas Kuhn's notion of the randomness of research in the absence of a guiding theoretical structure, or paradigm(5).

In a couple of incidents in the play, Shadwell also points at the supposed callousness of scientists when confronted with the possible social implications of their knowledge and its resulting technology. When Sir Nicholas suggests that with the perfection of his new speaking trumpet only one parson will be required to preach to all Englishmen on Sundays, his answer to the question of what will happen to all the other parsons is: "It is of no matter. Let them make woollen cloth or become fishermen."(6) When, toward the end of the play, the common people rebel when they hear a rumor that Sir Nicholas has invented a weaving loom, Sir Nicholas protests his innocence and suggests that his researches in science have no implications for society but are intended to pursue knowledge, even useless knowledge, for its own sake.

Of course, science has not remained isolated from society, and dramatists and poets in the next 200 years, either praise science for its effects on society, lament the effects of science and technology upon their romantic view of the world, or blame science and technology for its effect on the environment and on certain segments of society. The scientific community has, in fact, often been reluctant to consider the potential or actual consequences of scientific and technological advances on society. René Dubos writes: "During the second half of the nineteenth century, it was public pressure organized by enlightened laymen that placed environmental problems at the forefront of scientific endeavor."(7) In the last hundred years many scientists have, due to their special knowledge, or their particular jobs in industry or government, found themselves in situations in which difficult decisions involving science and society have had to be made.

In the play An Enemy of the People Henrik Ibsen (8), in the person of Dr. Thomas Stockmann, illustrates that the choices scientists might have to make when confronted with the implications of technology for society might involve considerable struggle and sacrifice, and, in Dr. Stockmann's case, might not even lead to a resolution of the dilemma.

Friedrich Dürrenmatt, in his play The Physicists(9), presents his three main characters with a number of possible courses of action in the light of the immense destructive power modern science and technology have given humanity. One of his characters, Johann Möbius, had willingly withdrawn himself from society and entered an insane asylum, after several of his fundamental discoveries had been used for destructive purposes by the military or industry. After some years both superpowers manage to infiltrate a physicist into the asylum, to determine whether or not Möbius is really insane. It turns out that Möbius's "indecipherable scribblings" are, in fact, the theoretical working out of a new fundamental theory which could have awesome military implications. One of the physicist-spies offers Möbius complete academic freedom to do pure research, paid for by the military. The consequences of his research would not be his responsibility, but might be for others to work out:

> "It seems to me, if it can restore the greatest physicist of all times to the confraternity of the physical sciences, any military machine is a sacred instrument. It's nothing more or less than a question of freedom of scientific knowledge. It doesn't matter who guarantees that freedom...".(10)

Möbius, however, cannot accept such a definition of scientific freedom which does not include the acceptance of some personal responsibility for the consequences of his research. The physicist sent by the other superpower offers Möbius another choice:

> "We (physicists) are providing humanity with colossal sources of power. That gives us the right to impose conditions. If we are physicists, then we must become power politicians. We must decide in whose favor we shall supply our knowledge, and I for one have made my decision... my political power, to be precise, lies in the fact that I have renounced my own power in favor of a political party."(11)

Möbius concludes that physicists cannot really be free in either system. He does not want to lend his talents and discoveries to risk the destruction of humanity:

> "I was poor. I had a wife and three children. Fame beckoned from the university; industry tempted me with money. Both courses were too dangerous... A sense of responsibility compelled me to choose another course... Our knowledge has become a frightening burden. Our researches are perilous, our discoveries lethal. For us physicists there is nothing left but to surrender to reality. It has not kept up with us... We have to take our knowledge, and I have taken it back."(12)

The only course open for the three physicists at the end of the play is to remain in the madhouse. However, even the sacrifice of withdrawal turns out to have been in vain. The director of the asylum has been photocopying Möbius's discoveries for years and is willing to sell these secrets to the highest bidder.

In the play In the Matter of J. Robert Oppenheimer(13) Heinar Kipphardt has a U.S. Security Officer, testifying against Oppenheimer, say

> "They (the scientists) should be made to realize nowadays, they are experts working within one vast enterprise. They have to do their own particular share of the work and then hand it over to the other experts, politicians and the military, who then decide what's to be done with it..."(14)

After the final verdict of the security commission is announced, and Oppenheimer is denied a further security clearance, (Kipphardt's) Oppenheimer reflects on the way science has evolved since the earlier days of Copernicus and Newton:

> "When I think what might have become of the ideas of Copernicus and Newton under present-day conditions, I begin to wonder whether we were not perhaps traitors to the spirit of science when we handed over the results of our research to the military without considering the consequences... I ask myself whether we, the physicists, have not sometimes given too great, too indiscriminate loyalty to our governments, against our better judgement... We have spent years of our lives in developing ever sweeter means of destruction... We have been doing the work of the Devil, and now we must return to our real tasks."(15)

Oppenheimer here echoes the point of view of Dürrenmatt's Möbius, the desire to withdraw from the real world and to return to a world of pure science, where the pursuit of knowledge has its own intrinsic rewards, a type of pure knowledge that has no evil consequences...

In The Life of Galileo, Berthold Brecht portrays the interaction of one scientist, Galileo, with the authorities of an earlier society and suggests that the dilemma faced by Galileo was actually very similar to that faced by Oppenheimer. In fact, both Brecht and de Santillana(16) insist that the conflict between Galileo and the church was not in the first place a battle between science and religion, but between science and authority, a battle which regularly recurs in different manifestations. Brecht's original intention was to portray Galileo "as an intellectually heroic figure, who fights for progress, who deliberately introduces a new age of unvarnished truth"(17). However, when Brecht began, with Charles Laughton, to prepare an American version of the play, the atomic age had made its debut.

> "Overnight the biography of the founder of the new system of physics read differently. The infernal effect of the Great Bomb placed the conflict between Galileo and the authorities of his day in a new, sharper light".(18)

The modern authorities, governments rather than the Catholic Church, had clamped down on the freedom of research, the exchange of information and the international fellowship of scientists. Suddenly Galileo became a different symbol for Brecht, not a courageous figure, fighting for the independence of science from authority, but as a traitor to science, who bowed to the authority of his day. In Brecht's own words: "Galileo's crime can be regarded as the "original sin" of modern natural sciences."(19) The actual crime? Galileo's recantation before the Inquisition:

> "I, Galileo Galilei, teacher of mathematics and physics at the University of Florence, renounce what I have taught, that the sun is the centre of the Universe and motionless in space, and that the earth is not the centre and not motionless. I renounce, abhor and curse, with all my heart and with sincere faith, all these falsehoods and heresies, as well as every other falsehood and every other opinion that is contrary to the teachings of the Holy Church."(20)

Nine years later, in 1642, a short time before Galileo's death, Galileo is still under house arrest and is visit by Andrea, a former student. Galileo has finished his major new work on mechanics, *The Dialogues Concerning Two New Sciences*, one copy written publicly and locked away by Galileo's jailers, and one written secretly, to be smuggled out of Italy and to be published in Holland. Andrea suddenly changes his opinion of Galileo. He had disapproved of his master's cowardly act of recantation but now realizes that the recantation enabled Galileo to finish his most important contribution to science. When Andrea lets Galileo know of his change of heart, he gets an unexpected reply:

> Andrea: Science knows only one commandment: contribute to science.
> Galileo: And that I have done. Welcome to the gutter, brother in science and cousin in treachery... I maintain that the only purpose of science is to ease the hardship of human existence. If scientists, intimidated by self-seeking people in power, are content to amass knowledge for the sake of knowledge, then science can become crippled and your new machines will represent nothing but new instruments of oppression... If only I had resisted, if only the natural scientists had been able to evoke something like the Hippocratic Oath of the doctors, the vow to devote their knowledge wholly to the benefit of mankind! As things now stand, the best one can hope for is a race of inventive dwarfs who can be hired for (21) anything..."(21)

Brecht's *The Life of Galileo* is a social commentary on the role of the scientist in society, and thus one should be tempted to ask whether or not the actual historical Galileo should be judged to have committed treason.

Gerhard Szczesny(22) in his commentary on Brecht states that it is a gross overexaggeration to consider Galileo's recantation as the original sin of science. He suggests that the charge of "social treason" can be justified by Brecht only by putting Galileo in a historical situation which simply did not exist in the seventeenth century. Brecht might have been able to make out a case of "treason" for Oppenheimer, Teller, Sakharov, and others who prepared weapons of mass destruction but, according to Szczesny, Galileo's treason is at most a personal, ethical one.

Brecht's original intention of portraying Galileo as a heroic figure, who is confident that science has the potential of ushering in a new age of prosperity and truth is mirrored in the Alexandrian scientist Phanocles in William Golding's "The Brass Butterfly"(23). In the play, set in Roman times, Phanocles, who believes the universe to be a giant mechanism, whose secrets can be understood and mastered, offers Caesar a number of inventions. These include an exploding missile, a steamship, and a pressure cooker. Caesar is rather bored by Phanocles's explanations of steam power, but promises to try the pressure cooker. However, Caesar does appoint Phanocles Director General of Experimental Studies. In the course of the play, while Caesar has to defend his crown against one of his potential successors, Phanocles tries to convince Caesar that support of this new science and technology will help to establish a new, and better society. Caesar, however, is skeptical of human nature and believes that technical progress will be a two-edged sword:

> "A steamship, or anything powerful, in the hands of a man, Phanocles, is like a sharp knife in the hands of a child. There is nothing wrong with the knife. There is nothing wrong with the steamship. There is nothing wrong with man's intelligence. The trouble is his nature."(24)

Caesar's skepticism seems to be borne out by events as Postumus, the pretendant to Caesars's throne, tries to use one of Phanocles's inventions, an exploding missile, against Caesar. However, the missile explodes prematurely, killing Postumus and demoralizing the attacking army. Caesar, relieved, appoints Phanocles ambassador to Cathay and wisely rids himself of this troublesome inventor.

Golding's view of science and technology is in many ways similar to that of Dürrenmatt. Both dramatists feel that science, whatever its motivation, inevitably becomes, in the hands of irrational human beings, an uncontrollable, possibly lethal monster. A basically good man, like Möbius or Phanocles, might fight against the irrational tendencies of human nature, but the battle will be lost, and barbarism will ultimately win out. In Golding's words:

> "We are today essentially what we were in the past, heroic and sick... though we have inherited the earth we remain hunters, using our weapons with the same seriousness and blind conceit that possessed the first of our kind."(25)

Conclusion

In these plays, the authors present a variety of images of science, scientists and technology. In Galileo's student Andrea and in Dürrenmatt's Jasper Kilton we recognize scientists who hold that the major goal of science is to develop knowledge for knowledge sake alone. None of the playwrights show much sympathy with such a goal. Golding suggests that, due to the basic irrationality of humanity, the inevitable result of such a pursuit of knowledge, will be the misuse of the technological applications of science and the eventual destruction of humanity. Kipphardt, Brecht and Dürrenmatt use the image of the Faustian bargain to suggest that the pursuit of knowledge for knowledge sake, whether supported by governments or military, exacts a price. Scientists will become so dependent upon the granting agency, that the only choices left may be withdrawal (with Möbius) or the establishment of a race of inventive dwarfs who can be hired for any purpose whatsoever (as Brecht's Galileo advises).

Brecht and Golding show much more sympathy for the view that the "only purpose of science is to ease the hardship of human existence". Both playwrights warn, however, that adoption of such a purpose requires the willingness to become a martyr: for Galileo, the Inquisition; for Phanocles, exile to Cathay, for others, perhaps loss of positions or financial support. Brecht holds out hope that such a choice by scientists can help to establish a vigorous, but perhaps smaller, community of scientists which can exist independently of government and military granting agencies. Of course society may not tolerate such an independent community that chooses to withhold certain technological implications from industry or military. In Dürrenmatt's The Physicists Joseph Eisler also appears to adopt the attitude of science and technology for the welfare of humanity, but does so in the service of a political party which supposedly has the same aims. Through Möbius, Dürrenmatt suggests that such an allegiance to a political party may also lead to an intellectual enslavement and a misuse of scientists' discoveries for destructive purposes.

Each of the plays portrays the scientists as politically very naive. Brecht's Galileo shows his naiveté by actually expecting that rational discussion will convince his opponents of the superiority of the Copernican System. Golding's Phanocles believes that the Emperor, and Roman society, will rationally embrace the bountiful gifts science has to offer and create a better existence for all Roman citizens. Ibsen's Dr. Stockmann also expected that the town council and his fellow citizens would rationally choose the best long-term solution to the polluted bath water. Dürrenmatt's Möbius exhibits his naiveté in believing that his choice of withdrawal from science, or of withholding the implications of his work from the military, will help to prevent those who are power hungry from using the technological implications of science in destructive ways. Even Kipphardt's Oppenheimer laments his own naiveté in perhaps having given too indiscriminate a loyalty to his government, or in having had too great a trust in the benevolence of military leaders to whom the "ever sweeter means of destruction" had been entrusted.

In each of the plays, the reader is left with the impression that crucial discoveries in science, or decisive events in the relation between science and society, revolve around individuals rather than on the scientific community as a whole. Perhaps only in Kipphardt's Oppenheimer does one sense a portrayal of a scientist as part of a scientific community, without which no single scientist could make major discoveries or advances. These plays show that the interaction of science, technology and society has been a topic of concern throughout the history of science, but becoming especially acute after World War II. In the form of plays, the problems portrayed demand the active intellectual participation of the audience of readers and have the ability to captivate the interests of students in science and science education.

I've used these and other plays in a variety of courses and teacher workshops. In undergraduate science education courses I've usually focussed on a particular play, usually one of The Virtuoso, The Physicists or An Enemy of the People followed by class discussions, whereas in a graduate course on Science and Society I've allowed students the freedom to choose from a greater variety of plays, which are introduced to the rest of the class by each student. Whereas the students are initially quite puzzled by having to read a play in a science education class, students have generally found it one of the most exciting and rewarding activities of the course.

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STS EDUCATION RESEARCH ROUNDTABLE

Peter A. Rubba (with M.O. Thirunarayanan, F.A. Staley, S.J.B. Westby, E.J. Zielinski, J.A. Bernardo, and F. Jenkins)

In a paper entitled, "The Current State of Research in Precollege STS Education: A Position Paper," presented at the Second Technological Literacy Conference (TLC), I argued the need for STS education to move away from non-scientific modes of decision making in curriculum development and implementation, instruction, evaluation, and teacher education/staff development.

> It was to be expected that precollege STS educational practice would be guided by logic, authority and experience during its emerging years. Still, there will come a point in time when precollege STS education will be judged by the standards of a mature, scientific discipline, by individuals operating within the area, but especially by individuals from other areas of education (e.g., science education, social studies education) wherein knowledge is built and decisions are made using scientific standards of evidence. If precollege STS education is not able to stand alongside of the other science-based educational disciplines, it may be cast aside. (Rubba, 1987, p. 250)

In addition, drawing on an analogy with the biblical story of "the house built upon sand," I inferred the need for an empirical research base in order to protect STS education from the whims of society.

> ... If we do not begin now to build a secure research foundation under precollege STS education, it is doomed to be swept away in the next tide of political and/or educational reform. (p. 251)

With foresight, the planners of the Third TLC provided an opportunity for individuals involved in STS education research to share their work at a Pre-Conference Session. I was given the opportunity to moderate the session. Over a dozen conferees who were able to arrive early, attended the session. Seven of them shared reports of STS education research projects they had underway or had completed. Many of the other session participants were scheduled to give research reports within the conference proper.

Five abstracts of research reports discussed at the session are presented here. These and other reports presented at the session represent the diverse nature of the research activities underway and needed to secure the viability of STS education. Names(s) appear in the heading of the abstracts and a short biography with address at the end of this article. Readers are encouraged to contact the researchers for more information about their studies. Readers of these proceedings also are encouraged to put their STS education ideas, methods and materials to empirical test in order to establish their veracity, and so, help build a scientific knowledge base for STS education.

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Proceedings of the Second National Technological Literacy Conference, Bull. Sci. Tech. Soc. 7 (1&2) (1987).

An Investigation of the Effects of Infusing STS Vignettes into High School Biology Instruction on Learner Outcomes in STS - Peter A. Rubba

Among the most popular techniques for infusing STS into extant science courses is the use of short STS vignettes. The purpose of the study was to test the effects of infusing STS vignettes, of the type suggested by Richard Brinckerhoff, into a segment of high school general biology instruction, as compared to not doing so, on student awareness of current STS issues, the importance students assign to current STS issues, and actions taken by students on current STS issues. The study was carried out using four sections of grade 9/10 biology taught by the same teacher using the Scott, Foresman Biology. The non-equivalent control group design was employed such that two of the four sections of biology were randomly assigned to each of two treatments. The experimental treatment (two classes, $n = 27$ and $n = 22$) consisted of the teacher orally interjecting STS vignettes, which were relevant to the day's biological material, in the closing portion of lessons twice per week over a period of six school weeks. In addition, once per chapter (every two weeks) the last portion of a class period was set aside for discussion of the vignette delivered that day and the associated STS issue. Over the six week period both the experimental and control classes ($n = 26$ and $n = 27$) completed their regular instructional activities on three chapters from the text: "Inheritance of Traits," "Gene and Chromosome Changes," and "The Monerans."

The four classes were pretested and post-tested with the STS Issues Questionnaire, (content validity established). Analysis of covariance was completed, with pretest data on the respective dependent variable and the mean of three chapter biology tests given over the treatment period entered as covariates. This yielded non-significant ($p < 0.05$, $df = 1,97$) F values on each of four dimensions of student awareness of STS issues: total STS issues stated, $F = 0.12$, total STS issues stated and justified, $F = 0.62$, total new STS issues stated (issues not used as examples on the questionnaire), $F = 0.78$, and total new STS issues stated and justified, $F = 0.45$. Pretest rankings by students of the three most critical STS issues facing mankind was maintained on the post-test. Analysis of covariance also yielded non-significant F values on STS actions taken, across the experimental and control groups, in total and within six action categories, i.e., civil, consumer, legal, persuasive, physical, political. It was concluded that the STS vignettes did not result in greater student awareness of current STS issues, perceived importance assigned to current STS issues, or action on current STS issues, over that resulting from biology instruction alone. The value of STS vignettes, at least as they were implemented and assessed in this study, is questioned.

It is recommended that science teachers who wish to integrate STS into science courses pursuant to developing action capabilities and behaviors in students, not rely solely on STS vignettes. STS issue investigation and action-based instruction, described elsewhere by Rubba and Wiesenmayer, is highly suggested to accomplish this objective.

First Year Results of a K-8 School-Community STS Curriculum Reform Project - M.O. Thirunarayanan and Frederick A. Staley

One year has elapsed of a three year project designed to reform the K-8 science curriculum with a science, technology and society (STS) emphasis in 25 science-communities from seven west Phoenix, Arizona school districts. The project, funded by the National Science Foundation and Arizona State University, is attempting to bring about this reform through the cooperative involvement of business/industry/informal education institutions with teachers, students and principals. The main research agenda of this project is to determine those factors which contribute to a school-industry-community's ability to bring about substantial curricular reform through the cooperative efforts of all those involved. Thus far three sets of data have been collected relative to this agenda.

First, the educators and non-educators involved in the project, after discussing what life might be like in the year 2003, were asked to rank order nine possible goal emphases in response to the question, "What ought we do now in schools to better prepare our students for the future?" The top three responses for each group were identical: more of an emphasis on a) thinking skills; b) basic skills; and c) science and technology. These results indicate, contrary to popular opinion, that both educators and non-educators have similar ideas about the emphasis that should be placed on curricular reform efforts.

Second, because a school-community's participation in the project was dependent on its principal volunteering and because of the importance of the principal in the school-community's efforts, it was thought important to find out why principals volunteered or did not volunteer for the STS reform project. Based on interviews with principals, two forms of an instrument were developed and administered to the 25 volunteering and 53 non-volunteering principals to ascertain their reasons for or for not participating in the project. Responses from 18 volunteering principals indicated the following: the main reasons for volunteering (mentioned by over 66%) were the quality of the project's intended goals, the positive potential impact of the project on basic skill instruction and the involvement of business/industry representatives in the project. The main reason given for not volunteering by the 41 principals who responded to the survey (given by 72% of them) was that the project would take too much time. Interestingly, almost 30% of these principals also thought the project would hinder basic skill instruction. This latter data contrasts with the perceptions of volunteering principals and suggests that principals who viewed based skill instruction as the "ends" or main focus of instruction, rather than as the "means" to achieve higher order thinking skills, were less likely to volunteer for this STS reform project. Results of this survey provide some insight about the conditions necessary for establishing a climate necessary for principals to volunteer to participate in STS curricular reform projects.

Third, the growth made in teachers technological literacy, as a result of their participation in a three week summer STS content academy, was determined. Thirty-three teachers selected by the twenty-five school-communities to serve as STS Resource Teachers attended seven 2 1/2 day presentations each with lab activities and field trips dealing with energy systems engineering, computer science, telecommunications, aeronautical technology, biomedical engineering and the sociology of science and technology. Smalley's Technological Literacy Test (1986) was given as a pre- and post-test for this academy. A Wilcoxon matched-pairs signed ranks test for differences between the pretest and post-test scores indicated there was a significant difference between the pre- and post-test for the total population of teachers. Using the Mann-Whitney U - Wilcoxon rank sum W test for differences in improvement score for various subpopulations of teachers, the following were found: female teachers had significantly larger improvement scores than males and those having taught more than 10 years had significantly higher gain scores than those with less than ten years of teaching experience. Significance was not established in improvement scores when the teachers were divided by the number of minutes teaching science per week, whether or not teachers had an undergraduate major in science and the number of credit hours of science taken in their undergraduate programs. Not one individual had a perfect score on the pre- or post-test, thus eliminating the chance of a ceiling effect with the data. Smalley indicated, however, the Technological Literacy Test needs further validation and standardization, thus leaving some room to question the results obtained. Smalley's correlation of test questions to nine behaviors of a "technologically literate" person provided fruitful analysis and self-appraisal for the STS Resource Teachers.

As this project continues into its next two years, further data will be collected which will further delineate the variables operating in a school-community's efforts to work cooperatively to reform their curriculum with a science-technology and society emphasis.

Perceptions of the Implications of High Technology for Minnesota Schools - Sandra J.B. Westby

Leaders in government, business and industry, and education influence state legislation, the employment arena and the educational process. The purpose of this study was to determine the perceptions of forty-five influential Minnesota leaders on issues related to education and the economy. Responses to interview and survey questions, a demographic questionnaire, and the field notes of the researcher formed the data base. Qualitative and quantitative methods were used to compare and contrast the collective responses of the groups. Significant statistical group differences were found on nine issues including the scale score correspondence of current programs and needs. Discriminant analysis of ANOVAS revealed the background variable of engineer was significant on six of eight issues.

The first conclusion of this study was that our society is rapidly approaching a juncture, defined as a point of time made critical or important by circumstances, a serious state of affairs, crisis. The second conclusion was the need for leadership. The data revealed a need to surface the issues and expand the public consciousness, a reluctance to have the federal government involved and a void in recognized leadership at the state level. The third conclusion was the need to focus on and support research and development in all related areas. The fourth conclusion focused on the system of education and stressed the need to understand and articulate the forces of change that impact the system of education and require new processes, programs and emphasis.

Specific recommendations included the establishment of a think tank. The objectives would be to raise the public consciousness of the issues involved and to serve as a visible signal of commitment, cooperation and community effort among the three sectors. Two possible products emphasizing research and development would be the establishment of a K-12 Lab School at the University of Minnesota and an emphasis at the post-secondary level on needs with corresponding efforts to coordinate studies and resources.

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The Effects of a Summer STS Workshop on the Knowledge, Attitudes, and Stages of Concerns of Secondary Science Inservice Teachers and Their Students' Acquisition of Knowledge - Edward J. Zielinski and John A. Bernardo

The purpose of this investigation was to determine the effects of a two week summer workshop on science, technology and society topics and methods of implementation into the classroom on the knowledge, attitudes, and stages of concerns of the participating secondary inservice teachers as well as possible impacts on the acquisition of knowledge of their students in the subsequent semester. This research was conducted using a modified pretest-post-test control group design. The participating teachers identified a peer whose teaching assignment was similar to their own. These teachers and their students served as the control. Participating teachers and their peers were pretested prior to two weeks (70 hours) of instruction and post-tested at the end of the workshop. The participating teachers implemented a ten day unit concerning STS into their traditional classrooms and pre- and post-tested their students and the students of their peers. Knowledge was tested using an instrument designed by the investigators with established content validity, test-retest reliability (r = .84) and an internal consistency estimate KR-20 (r - .82). The attitudes instrument was designed by the investigators with established content validity, reliability test-retest (r = .77), and internal consistency (KR-20; r = .75). The Stages of Concerns Questionnaire (Hall, et al., 1979) is an established instrument with well known estimates of reliability and validity. Only face validity was assumed for the teacher-made student achievement test. Covariant analysis was used to evaluate the effects of the treatment at the .05 level of significance.

This investigation yielded several significant findings. The participating teachers N = 22 exp. and N = 17 control concerns were lowered at the following stages: Awareness (F = 45.9, df - 1.36, p = .000); Information (F = 11.8, p = .002); Consequence (F = 16.9, p = .000); Collaboration (F = 29, p = .000); and Refocusing (F = 26.5, p = .000).

These results are supported by the significantly greater scores on the achievement test obtained by the experimental group (F = 115.2, df = 1,35, p = .000). Their Knowledge and Awareness levels of concerns were lowered as their knowledge increased. The attitudes (approach tendencies) of the teachers who participated were significantly increased in the direction judged to be positive (F = 9.3, df = 1,35, p = .005) when compared to the control group of their peers. In addition, the students (intact classes N = 11) of the teachers who participated in the STS program achieved significantly higher scores on the teacher-made achievement tests than did the control (intact classes N = 9), (F = 35.5, df = 1,17, p = .000). The results of this investigation indicate that a two week summer inservice workshop can be effective in reducing teacher concerns, increasing content knowledge and approach tendencies toward STS topics. In addition, this information was successfully transferred to the students of the participating teachers. Refinements of the instrumentation including subtest development are underway and additional data are being collected to further determine the effects of differing models of STS inservice workshop presentation. Additional research will be needed to determine effective and desirable evaluation models and delivery methods.

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This research was partially supported by the Pennsylvania Science Teacher Education Program (PASTEP).

A Taxonomy of Curricular Discourse - Frank Jenkins

The purpose of the study is to develop a Taxonomy of Curricular Discourse by taking a multi-perspective view of science textbook discourse. The approach used is conceptual analysis. The five theoretical perspectives which are the basis of sentence by sentence analysis of textbook discourse are: epistemology of science, normative perspectives, curriculum emphases, practical inquiry, and science-technology-society (STS) education. These perspectives provided criteria for testing the validity of the taxonomy which evolved in the course of analyzing and classifying six chapters of high school chemistry text. The taxonomy represents an attempt to make epistemology accessible through the language of the practical, as distinct from the language of philosophy. The major findings of the research was epistemological. An epistemological triad of resultant knowledge, procedural knowledge and required action was discovered to be present in all science textual discourse. The triad conceptualizes the relationship among the "what?", and "how?", and the "action required" components of discourse.

From a normative perspective, ten knowledge forms were initially identified as being valued by various interest groups within chemistry. From a curriculum emphasis perspective twenty-two knowledge forms are subsumed within five curriculum emphases: science, technology, society, communication, and pedagogy. An alternative definition of science-technology-society science education in terms of conceptual, descriptive, process, and epistemological knowledge forms is developed. A research-practice dialectical relationship with an ongoing curriculum project was employed. Epistemological harmony with practitioners was sought by developing a language for explicitly introducing epistemology into science teaching. The Taxonomy of Curricular Discourse is presented as a point of departure for the examination of the nature of curricular knowledge in science and its ongoing pedagogical purposes.

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SCIENCE ANXIETY AND GENDER

Jeffry V. Mallow

The recognition of "science anxiety" as a malady affecting students, working adults, even teachers, is by now commonplace. National commissions call for its alleviation (NRC, 1982; NCEE, 1984); and proposal requests from the National Science Foundation among others, urge that programs designed to bring more women and minorities into the sciences include anxiety reduction as part of their activities (NSF, 1987).

The Science Anxiety Clinic

The identification of fear of science as a factor in student avoidance of, or failure in science courses, began in 1977 when I observed that many students who were otherwise good scholars, even in mathematics, were experiencing inordinate difficulty in their science courses. I coined the term "science anxiety," and with the Counseling Center staff at Loyola University, founded the first science anxiety clinic (Mallow, 1978A). The clinic, co-facilitated by a scientist and a counseling psychologist, treats groups of 6 to 10 self-identified science-anxious students in a seven-session, two-hours-per-session regimen comprised of three components: science skills training (Mallow, 1978B), cognitive restructuring (Ellis, 1962), and relaxation and desensitization training (Jacobson, 1938; Wolpe, 1958).

The first of these components is self-evident. Students are explicitly taught the skills necessary for learning science: analysis vs. memorization, note-taking in a science lecture, laboratory techniques, and many others.

Cognitive structuring involves the identification of negative "self-statements" about one's ability to do science. An abbreviated list includes:

(1) No matter how much I study, I'll never understand science.
(2) If this problem looks easy, it's probably because I don't really understand what is asked for.
(3) If I ask the teacher a question, I'll show how dumb I am.
(4) Everyone else understands the material.
(5) Boys are supposed to be good in science.
(6) Science is not for girls.
(7) If I miss this problem on the exam, I may fail it. Then what if I also fail the next exam? And the next?

The replacement of these with objective "coping statements" constitutes a large portion of the clinic activities.

Relaxation training is a method of teaching students to relax various muscle groups on command. This is coupled with "systematic desensitization" to a hierarchy of science-anxiety-producing events, ranging from homework assignments to exams. An abridged hierarchy includes:

(1) On the first day of classes you are standing in the bookstore thumbing through the textbooks for your physics course.
(2) You are sitting in your physics class. You raise your hand to ask a question.
(3) While trying to solve one of the physics problems in your homework, you use several different formulas and get several different answers.
(4) While you are taking a quiz, your instructor walks past you and pauses, looking at your paper.
(5) During a lecture you don't understand what your instructor is saying, but you notice that everyone around you is nodding and rapidly writing down notes.
(6) You have just been handed the final exam.

Research Results

In the 10 years that the clinic has been operating at Loyola University, several hundred students, from liberal arts to science majors, have availed themselves of its services. Alvaro (1978) and Hermes (1985) carried out detailed studies of the clinic students as compared with controls, students who applied to the clinic but for whom there was no room in its schedule. These studies included standardized tests of math anxiety (Richardon and Suinn, 1982), test anxiety (Alpert and Haber, 1960), "state" vs. "trait" anxiety (Spielberger et al., 1970), and a specially constructed test for science anxiety (Alvaro, 1978) validated for a sample of 480 college students at Loyola. In addition, pre- and post-tests of muscle tension were carried out, using electromyography. Both Alvaro and Hermes demonstrated that students who had been treated in the clinic had significantly lowered levels of science (and other) anxiety than the control group.

Results of experiences in the clinic, as well as research results, were summarized in a book by Mallow (1982); a revised edition was published more recently (Mallow, 1986).

Gender-Specific Science Anxiety

While the clinic is effective in lowering anxiety of both men and women to the various sciences, specific application to women, who make up 2/3 of the clinic attendees, and specific attention to physics, as that science perceived by most, and especially by women, as the hardest, has been the focus of more recent work by myself and others. Mallow and Greenburg (1983) described the specific applications of science-anxiety reduction techniques to physics students, synthesizing studies of convergent and divergent thinking (e.g., Feldhusen et al., 1965; Cropley, 1967; Cropley and Field, 1969), and Piagetian measures of physics learning (Renner et al., 1976; Gauld, 1979) with our own observations of clinic students.

Gender differences in the decision to study science have long been observed. One of the earliest studies was carried out by Walberg (1969). He suggested that the differences in "abilities, motives and outlooks between boys and girls studying physics" in the last two years of high school were the result of the greater disposition of girls towards "docility, dependency, and willingness to work for social approval." These traits led to higher grades in high school science, but were the very factors working against success in science at the college level and above, where assertiveness, independence, and disinterest in approval were correlated with scientific success. Subsequent studies (Renner, et al., 1976) similarly pointed to behavior differences that inexorably drew girls away from science. A host of studies in the last two decades (see e.g. Mallow, 1986 and "Bibliography of Women and Science" therein) corroborate and expand on Walberg's early findings. The recent work of Zerega et al. (1986) states: "Science may still be viewed as a male domain ... Girls are not supposed to be good in science, and so they confirm what peers expect."

Gender-Specific Interventions

Yet, progress has been made. Renner et al. (1976) describe certain teaching methods which minimized gender differences in the classroom. White and Tisher (1983) quote a number of studies which isolate various teaching-based gender differences. The general rubric under which these various teaching methods fall has come to be called "classroom climate," and includes such factors as level of questions asked, wait-time between question and answer, choice of topic to investigate, and approach to the study of the topic.

In the last few years, two important changes have occurred in the field of gender differences in science learning. The first, as noted by White and Tisher (1983) is that the recognition and study of the problem has become internationalized. The second is that results of the research have begun to find application both in the classroom and in the training of science teachers. In the U.S., one application has been the Workshop on Developing Student Confidence in Physics, presented by the American Association of Physics Teachers to groups of physics professors and high school teachers at the AAPT's semi-annual national meetings. The focus of the workshop is to assess and modify teaching styles in order to make the classroom anxiety-free in general, with special emphasis on the situation of women and minorities. The workshop manual produced (Fuller et al., 1985) is now used across the U.S.

The Danish Physics Project

In Denmark, Beyer and co-workers, all classroom physics teachers in gymnasium and/or university, have been investigating gender differences as well as implementing changes and observing their effect on physics learning of young women. Their work (Beyer et al., 1985) focuses on the interaction of cognitive and emotional factors as they affect two gender-sensitive features of physics education in the gymnasium (ages 16-19): classroom climate and learning styles. They report that Danish girls, like their American counterparts, are physics avoiders in much larger numbers than boys; that parental, peer, and societal expectations are correlated with this avoidance; and that girls generally manifest a lower level of self-confidence, regardless of their demonstrated competence in the physics classroom. While unsurprising, these results confirm that girls' physics avoidance is a phenomenon which transcends national boundaries.

Even more interesting are results which one might not have expected, and which suggest several areas for study. One is the observation that girls prefer "thematic" organization of the subject matter, rather than the standard treatment of topics; further, that they are most interested in certain themes which they find "relevant" to their lives. Yet, when asked to compare physics and mathematics, they seem to prefer mathematics, which lends itself to the "relevant theme" approach even less than physics. Beyer, et al. hypothesize that girls see mathematics as well-bounded, with a clearer set of requirements and fewer open-ended applications than physics. This corroborates our own observations (Alvaro, 1986; Mallow, 1978) that math anxiety (Tobias, 1978, 1987) and science anxiety are distinct, decoupled phenomena. Beyer, et al. also find that girls lose confidence more rapidly than boys, and switch from analysis to rote-learning of physics materials; perhaps, they suggest, because of girls' higher discomfort level with "accommodation," the reorganization of cognitive structure as new ideas are assimilated.

Finally, Beyer et al. find evidence that members of the Danish education community discourage girls from studying physics, under the guise of not "imposing" choices on them. Once again, this agrees with anecdotal data from our and other science anxiety clinics in the U.S.

Future Prospects

The studies of Beyer's group, coupled with our own work in science anxiety clinics, may increasingly clarify the connections between science anxiety and gender, bringing, we hope, the implementation of specific interventions to help women overcome their fears of science and assume their rightful place as science students, teachers, and researchers.

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DO IT, THINK ABOUT IT, TALK ABOUT IT: SCIENCE DEVELOPS GIRLS' LEADERSHIP SKILLS

Rachel Theilheimer

> Jamaica leans over her bike, oil can in hand. Figuring out exactly where to lubricate, she reaches to get at the back gear. Later, she comments, "...it looked complicated, 'cause it was all greasy and ucky and dirty! At first, I didn't want to [do it]. But, dirt ain't that bad after all! It's kind of fun when you, like, fix the wheel, and you feel good about yourself -- because you know that _you_ can fix it!"

Jamaica is one of thousands of girls all over the United States who is gaining the confidence to master technology through Operation SMART (Science, Math, And Relevant Technology). In Operation SMART at her local Girls Club, she does science and technology-related activities; she thinks about them; she talks about them to adults and other girls. Through this process, she grows to understand more about the role science and technology has to play in her life. The more she understands, the more she influences other girls. They see her, a confident, popular girl, involved in science and want to emulate her. They hear her excitement as she figures out the world around her, and are convinced that they want the same for themselves.

Operation SMART is a project of Girls Clubs of America, Inc. designed to make science, math, and technology part of girls' everyday experiences. Girls Clubs of America serves 250,000 girls and about 40,000 boys each year in 240 Club centers across the country; two-thirds are from families earning $15,000 or less per year and half are from racial or ethnic minority groups. Girls Clubs provide informal education and recreation to girls ages six to 18 in buildings that the Clubs own.

The first Girls Clubs began during the Industrial Revolution as safe places for the girls and young women who worked in the Northeastern mills and for mill workers' daughters. One hundred years later, through Operation SMART, we continue to respond to a changing, increasingly technological society.

SMART was established in 1985 in response to the underrepresentation of women in science, math, and technology. We focused initially on issues of access, providing girls with the chemistry set that only their brothers were given, the blocks that boys monopolized in their nursery schools, and the computers that they were too timid to fight for in school.

It quickly became apparent that access is not enough. Many characteristics of scientists are precisely those that are discouraged in girls from early on -- taking risks, getting messy, making mistakes and trying again. Questioning, exploration, and scientific inquiry, the mainstays of good Science Technology and Society (STS) curricula, then became the crucial elements in all activities at Girls Clubs. Inquiry fits into every part of the Girls Club: as girls work together to figure out how to shoot baskets most effectively in the gym, determine which are the most energy-efficient swimming strokes in the pool, or mix colors to obtain desired results in the art room.

If science is to become a tool to help girls take charge of their futures, we must find science-related activities that put the girls in a position of power. We sought activities that address the issues of today's technological society and that use scientific methods to pursue the questions of interest to girls. Girls tested the pH level of the local pond water. They planted community gardens. They designed cities of the future.

Reflection, thinking and talking about activities as they happen, was always a part of Operation SMART. With the addition of an adolescent component to Operation SMART, reflection took on new dimensions. The girls' penchant for discussing what they do and think supports work on early adolescents that advises reflection as an important element (Schine, 1981). With this in mind, a set of three criteria for equitable and excellent out-of-school science programming for early adolescents emerged:

1. Activities must be hands-on. Girls must have experiences with materials and tools.

2. Activities must entail invention. Girls must have opportunity to figure things out for themselves and to solve problems that are important to them.

3. Activities must include a reflection component. Girls must have time to think and talk about what they do.

The reflection component serves several functions. Girls think about what they have done and work together for improved solutions to their problems. Such collaboration makes science more appealing to girls and more rigorous for everyone. Truly responsible science is the result of several people working together, checking one another. Reflection time also provides girls with the opportunity to delve into the ethical and moral issues that make science more inviting and interesting to them and that are essential if science and technology are to have a positive impact on the future. Lastly, reflection enables girls to look at their attitudes toward math and science and make connections among science activities at the Club, science lessons in school, science that could be a career track for them, and the scientific and technological literacy they will need as responsible adults.

To girls reflection means: DO IT. THINK ABOUT IT. TALK ABOUT IT. Girls do science at their Clubs, explore a museum, or take a trip to talk to a woman in a science-related or technological career. As they think about their experience, they come to know themselves better and increasingly regard themselves as young people who have real choices to make. As they talk to their peers about their experiences with science and technology, they become leaders. They become the most persuasive advocates that science and technology could have.

Three aspects of Operation SMART that promote leadership through science are:

1) Inventive, hands-on science including reflection and access to role models,

2) Peer leadership training at a science museum,

3) Girls as social scientists.

1) Inventive, hands-on science including reflection and access to role models. As girls connect wires to light a bulb, build machines with pulleys, and create clouds inside large glass bottles, they get their hands into the physical sciences. Knowing that women are significantly underrepresented in physics and engineering, SMART makes a conscious effort to offer girls experiences in these areas.

Besides experience, role models are the key to making connections between math or science and the real world (John-Steiner, 1987). A visit to General Electric's Research and Development Center made the difference for Danielle who discussed her math teacher with a female statistician there and later said:

> Well, I used to like math a lot, and I always wanted to do something with math. But then I got teachers that I didn't really like, so it kind of turned me off on math as a whole. But now, after talking to different people about it, they say it's still a good idea and just to separate it from the teacher. So I think maybe I can try and do that, and maybe I'd like it more again.

The statistician worked daily with mathematics, was attractive, and seemed to enjoy her job, so Danielle really listened to her.

2) Peer Leadership training at a science museum. Peer leadership was an elusive notion we had of girls influencing one another to pursue science. Working with the Museum of Science, we envisioned museum experiences helping girls develop their skills as leaders, as people who try new things, reach out and listen to others, and share with their peers what they know and feel.

In November 1987, 36 girls who had never met before explored the Museum of Science in Boston together. Their charge was to find out "What was awesome? What would you change? How will you explain what you saw to others?" Maps in hand, they went onto the museum floor, leading one another with, "Hey, look at this. Come on over here!"

Girls got excited about static electricity, frozen shadows, and baby chicks hatching from their shells. Critical of exhibits that did not have enough to do or that were in disrepair, enthusiastic about computer games, they took one another to share their discoveries.

Girls see the connection between science and leadership when they realize that power is inherent in science. Their favorite exhibits were ones that required strength or strategic thinking. Girls loved exhibits that challenged them to understand the underlying scientific principles.

Girls will return to the Museum of Science for more sessions to promote the connection between science and leadership. Going behind the scenes to see science jobs at the museum and gathering materials and activities for their Clubs, they will pursue the idea of leadership through science.

3) Girls as social scientists. Instead of using traditional evaluation techniques for Operation SMART, Girls Clubs of America is developing a Research Tool Kit that puts the power of project evaluation in girls' hands. Using activities that turn them into social scientists, the Tool Kit enables girls to discover how science activities have affected their own and each other's attitudes, interest in, and knowledge about careers in science, math, and technology.

The tools are activities that girls do before regular science activities at their Clubs and that they do again afterwards, evaluating the changes in their own and each other's responses. For example, in one activity they examine ten photographs of girls involved in science or technology in ten different ways. They rate each photo, and then collate the group's data, revealing the range of reactions to each photograph and arriving at a composite picture of their group's attitudes about, interest in, and previous experience with ten aspects of science and technology. In later months, girls will repeat the photo-rating activity to find out whether experiences at the Club have affected their views.

Once again, girls are doing, thinking, and talking, using themselves and one another as resources for personal growth. Being among the project evaluators, they necessarily take a leadership role, thinking about what math, science, and technology can mean for them, their futures, and the futures of their peers.

Through all three aspects of the Operation SMART program, girls' individual involvement in science is broadened to affect the girls around them. They share their excitement and actively influence their friends to reconsider science and they quietly become role models displaying the power of science.

The result of Operation SMART at Girls Clubs all over the country is girls who will be prepared to take a stand for responsible scientific and technological development. No matter what careers they choose, they will not have cut off their options at an early age. Clear about the role science and technology play in today's world, these girls will be able to encourage their friends to join them in taking power over their own futures.

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INVENTION AS PROBLEM-SOLVING: SPECIAL CONTRIBUTIONS OF FEMALE INVENTORS

Fred Michael Amram

In 1985 only 8% of U.S. patents granted to U.S. residents included the name of a woman (up from 1.5% in 1951). Furthermore, the distribution among types of patents (e.g. tools vs. products, chemical vs. mechanical) differs for men and women.

Technology shapes the world in which we live and thus shapes society itself. In turn, society guides the questions which guide technological inquiry--and thus the direction--of technology itself. If women make little or no contribution to technology, they consequently have less influence on culture in general.

Contributions to technology can be measured, in part, by invention. Inventors, then, are agents of change. This paper defends three assertions as part of an exploration of women's contributions to technology: 1) women, largely excluded from the world of invention, have had limited influence on technology; 2) women, like men, use their inventive genius in those areas where they confront
problems; 3) women's inventive styles and values are probably no different from those of men.

1. Women's Limited Influence as "Change Agents"

To invent is to change what exists into something new. Changing the status quo with social inventions or material inventions involves control and power. So long as women's behavior toward technology reflects "passivity...compliance...dependence" (Spitzack and Carter, 1987) they will not participate in technological change in equal numbers. So long as women do not participate equally in technological change they are excluded from influencing the direction of technology and, consequently, all culture--and the cycle in which women are caught continues. Inventors are change agents and therefore more immediately powerful in their impact on culture than other scientists.

Women's creativity has clearly not been directed toward technological invention. Roughly 2% of U.S. patents granted to Americans during the past 200 years cite the name of a woman. How would material culture be different if the number of inventions by women were to increase
significantly?

There is no effort here to deny or to trivialize women's substantial contributions to science. However, the major contributions women have made to science are in observing, counting, and cataloging--not inventing. The contributions of astronomer Maria Mitchell were different from those of inventor Marie Curie. In 1873 Maria Mitchell founded the Association for the Advancement of Women partly as a response to her concern that there were so few women scientists. Interestingly, she noted that "Nature made woman an observer" (Weimann, 1981).

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Observation and cataloging are important and often lead to the applied science of the inventor. Nevertheless, for the most part, women have been the catalogers and men the inventors. Yet some few women have made major inventive contributions.

Two cases distinguish the two styles. First is botanist Maria L. Owen, whose lifetime contribution to botany are her catalogues of Nantucket plants (Smith, 1987). Consider the difference in impact on culture of Barbara Askin's U.S. Patent (#4,101,780) for "obtaining intensified images...on film." Owen's observations may have indirectly affected Nantucket's ecology. Askins, on the other hand, as a NASA inventor, developed a process that directly created change. Her invention enhances photographs taken at great distances from spy planes. Subsequent applications enrich faded and aged personal pictures and increase the safety of exposure to X-Rays by minimizing exposure time.

This does not trivialize the scientific contributions of cataloguers. But inventors like Dr. Ruth Benerito contribute directly to cultural change. Her inventiveness helped to pioneer wash-and-wear.

Inventions are usually intended to improve one's material or social environment. Such improvements generally provide greater freedom. Inventing latex undergarments and swimsuits provides women with greater physical freedom. The nineteenth-century Dress Reform Movement was built on greater participation of women in the process of inventing clothing to free women from the "bondage" of restrictive and unhealthy clothing. Certainly an improved washing machine or knitting machine provides greater personal choice and initiates change in role expectations.

Women can increase their power over technology by increasing their participation in the invention process. At minimum, girls and women should feel comfortable with the concept that "woman's work includes invention," and boys and men must accept women as change agents. As women increase their participation in invention their new power will surely be recognized--and perhaps feared. The chief patent counsel of one of America's major corporations refused to cooperate with this author's research project. Most telling (and, in a sense, documenting the argument that inventing is a "power statement") was his assurance that women are receiving more patents than ever before. "In fact," he added, "at this rate we may be living in a matriarchy in fifteen years."

Inventing is a statement of power! Women's powerlessness, however, has been taught as a cultural paradigm and occasionally girls are clearly and specifically taught that inventing is inappropriate behavior. In a 1970 children's book a little boy is shown tinkering with tools and scraps. In a second illustration a girl sits in a chair under a lamp clearly "jerry-built" by the little boy. The caption under the first picture is, "Boys invent things." The second caption reads "Girls use what boys invent" (Darrow, 1970).

Berner (1983) summarizes the case: "During the...[period] 1880-1940 an ideology of separate spheres for women and men--domestic for women and occupational for men--prevailed and manifested itself in education, work and professional organizations."

2. "Inventors Invent Where They're At"...

Almost everything around us was invented in a particular place, at a particular time, for a particular purpose. This suggests that inventors must be in the right place, at the right time, must be aware of the problems and feel capable of solving them. Thus one can examine women's inventions by looking at their "place" in the context of time and their proximity to problems and appropriate skills.

Inventors usually begin with a problem and some special knowledge or skill to provide a solution. Bette Graham, for example, was a secretary. When she typed an error she used an eraser. The development of carbon ribbon improved the quality of type but made the eraser ineffective. Ms. Graham had a special skill. She had studied art and reasoned that she could cover mistakes just as an artist does--by painting over the error. It took a great deal of effort to find the perfect formula for a "paint" that is thin, yet covers completely and dries quickly. Bette Graham's Liquid Paper eventually made her rich.

Harvey Green (1981) writes that "Sewing was the most frequently recorded domestic labor performed by middle-class women. They sewed their...clothes...as well as...most of their husbands' and sons' clothing...." Is it any wonder, then, that women received many patents for sewing-machine- related items which would ease their work? Notable is Helen Blanchard, whose 24 patents included a variety of sewing- machine attachments which helped to make sewing machines more useful. The American Buttonhole, Overseaming & Sewing Machine Company prospered because of her many inventions. Mrs. H. R. Tracy's "Lock and Chain Stitch Sewing Machine" and her commercial bobbin, which holds 1,000 yards of thread, contributed to commercial clothing manufacture. Hannah Suplee patented a variety of sewing-machine-related inventions, including an improvement in sewing machine needles which is now on display at the Smithsonian.

The first numbered patent (#5,590) for a sad iron was granted to Mary Ann B. Cook on December 5, 1848. Ms. Cook's patent recommends her improvement as especially useful "for smoothing and polishing shirt bosoms..." (Swanson, 1988). Like Bette Graham and others, Mary Cook had a special knowledge of the problem: "Common...sad-irons...have only one flat ironing or plane surface. They are not well adapted to polishing or glazing starched shirt-bosoms or other articles." Like Bette Graham and others, Mary Cook had special knowledge to provide a solution: "Experience has taught me that a very high gloss or polish can only be successfully or practically effected by a small curved convex surface, one capable of retaining a suitable polishing-heat while being used."

What kind of history could we learn from Eliza Wood who, in 1891, received a patent for a Mop Pail and Wringer, versions of which are still used today? Was she, perhaps, a "charwoman" with a special creative talent who had access to some technical skill?

But women's patents do not always revolve around the home. For example, two Minnesota women invented rather sophisticated farm machinery. Anna Trexler's "Combined Plow and Harrow" (1888) and Lucy Easton's Flaxseed Separating Machine" (1890) indicate that they must have been close to the problem.

The bedpan story is startling. In the 198 years of the PTO roughly 2% of the patents granted to Americans have been registered by women. Roughly 46% of the bed pan patents were granted to women. Shocking? But consider that people find problems in their immediate environment. Women traditionally cared for the sick and for aging parents.

Eighteenth- and nineteenth- century U.S. patents granted to women centered around health, fashion, and home because that's where women saw problems. Women with appropriate skills, mixed with imagination and daring, invented to improve their situation. Circumstances took some women to other arenas where they responded with appropriate creativity. The principle is the same: women invent in response to problems they face.

Harriet Strong is a grand example. When she was sick, in the early part of her life, she invented a device which helped her open and close windows. It consisted of a curved hook at the end of a long pole which fit into a recess built into the upper window sash--a "window pole" most readers will recall and which is still in use today. She subsequently invented a hook and eye, versions of which are still in use, and a window sash holder which allows windows to be positively secured in any open position.

After the death of her husband, Harriet Strong had to manage the California "dry" ranch which she inherited. Ranchers in the Southwest could not cope with the irrigation problems they faced. In 1887, she patented "an improved design for dam and reservoir construction in which a series of dams were laid out like steps. These dams-in-series were stronger and safer than a single dam; used close to the source of water, in canyons, for example, they could provide a regular supply of water to lands downstream" (Albertine, 1988). The idea, thirty years ahead of its time, was denounced as unsafe and impractical. A related patent for a new method for impounding debris and storing water (to be used with her series of dams) won Harriet Strong a medal. She was cited for "the practical application of her method in hydraulic mining." Eventually she became the "mother" of the Colorado River Project.

Harriet Strong illustrates well the principle that people invent "where they're at." When she was "housebound," she invented solutions to problems in her immediate environment. When she was exposed to a new sphere, her inventions solved new problems and she used technology to influence her new environment. As women are employed by NASA they may invent processes which improve the world of spying as did the work of Barbara Askins. As women study agricultural chemistry they patent new herbicides, as did, for example, Florence Gleason in her patent for a "Cyanobacterin Herbicide" (1986). When they work for major industries (e.g. Honeywell Inc.), they patent electrical "isolation devices" for use with electronic integrated circuits (Rahmian, 1984) and "piezoelectric" pressure sensors (Royer, 1984).

3. Women's Inventions Reflect Setting Rather Than Style

The percentage of patents granted to women is slowly increasing. Important questions emerge. How would the direction of technology change if the number of patents granted to women increased significantly? How would material culture be affected if the distribution of the kinds of patents granted to women were to change significantly?

While no formal research exists to answer these questions, this author asserts that "people invent where they're at." As women move into new spheres, they, like men, will solve the problems of those new spheres. There is no evidence that women in laboratory settings or in industrial management positions do, or will, behave differently from men.

Nor are women more humane than men in their development of technology. When women go to war, usually as replacements for men in manufacturing industries--Rosie the Riveter--they invent to fill perceived needs. Thus a post WWI report from the Women's Bureau of the Department of Labor cites some sample women's inventions (U.S. Department of Labor, 1923):

Automatic Pistol
Bomb-Launching Apparatus
Cane-Gun
Rear Sight For Guns
Mine
Percussion & Ignition Fuse
Primer
Railway Torpedo
Single Trigger Mechanism Submarine
Torpedo Guard

And Marguerite Shue-wen Chang has at least eight patents, including one for a device that triggered an underground nuclear explosive in a 1969 Atomic Energy Commission test.

So What?

Several lessons are to be learned from these explorations:

1) Women, because they have been largely excluded from the world of invention, have had little influence on technology.

2) Women, like men, use their inventive genius in those areas where they confront problems. Consequently, 19th- century women patented primarily in areas relating to dress, the household, and care-giving.

3) There is at this time no evidence that women use inventive styles in ways different from men nor that their inventions reflect a different morality. The virtues of the Madame Curies are matched by the virtues of the Louis Pasteurs. The inventors of weapons can be found everywhere.

If women will not invent differently from men, why must we encourage their participation in technology? Because we have, throughout western history, lost almost half of humanity's potential inventors. Economic survival depends on new ideas, new products, and new social inventions. We should not waste half of our potential. There is no evidence that women will invent differently--but they can invent more.

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THE STS PROGRAM AS A VEHICLE FOR DISCUSSING ISSUES OF ETHICS AND VALUES

Morton Tavel

Several years ago Vassar College hosted a conference (funded by the EVIST program of NSF, Grant No. OSS-7906976) on teaching ethics and values in undergaduate college science courses. The participants were science teachers who had already decided that the discussion of ethical and value-laden issues was necessary at some stage of an undergraduate science education. The concerns raised at the conference were not whether ethical matters should be taught, but rather how they should be taught, who should teach them and what the goals of the instructor should be.

Four concerns were voiced. 1) Because of the fullness of the science curriculum, adding material on ethics requires subtracting material from the scientific subject matter. 2) Science courses establish an atmosphere of "hard" objectivity and rely on an essentially dogmatic pedagogy; ethical issues tend to be "soft" and subjective and require an argumentative pedagogy. This leads to a serious mismatch between the subject matter and lends a sense of artificiality to the introduction of ethical issues. 3) Science teachers are seldom trained as ethicists and do not have the pedagogical skills to deal with such contentious material. Are they the ones to do it? 4) Every science teacher knows the goals of a given science course and can test the students to determine how well the goals have been met; the comparable goals and testing mechanisms when teaching about ethical issues are much less clear.

I cannot state that each of these concerns were answered to everybody's satisfaction and that conference participants returned to their institutions with all traces of self-doubt eradicated. It was established, however, that the subject matter of modern science and its dominant (if not dominating) role in our society assures us that ethical issues will continue to be raised, that these issues will disturb the thoughtful scientist and possibly affect his or her work and that we, as educators, have an obligation to our students to prepare them for this facet of their professional lives.

My aim in this paper is not to address the ethical education of a scientist, but to face a related, albeit broader and potentially more significant problem: presenting the ethical issues raised by both science and technology to a general college audience. Although this problem is more encompassing than the development of an ethical component for a science education, it may be more amenable to solution. I make this rather paradoxical statement because STS type programs, which are increasingly to be found on college and university campuses, are more accessible to a general audience and offer the kinds of courses that can readily and naturally deal with the issues in question. In what follows, I will enlarge on this proposition.

A distinction must first be drawn between any presumed role of a college in forming moral character and its role in educating the public in understanding the ethical bases of the problems that beset modern society. In fact, I do not believe that the public or private secular college has any business imposing a particular moral stance on its faculty or students through its courses or otherwise; I do believe that the college has an obligation to expose students to the moral underpinnings of behavior and to the ethical implications of scientific research, scientific discoveries and technology in all its ramifications.

A brief but excellent retrospective on the historic role of colleges in providing ethical education was given by Dean Patrick Sullivan of Vassar College at our conference (1). I will paraphrase some of his most salient points.

Nowhere in the medieval college curriculum was there any ethical instruction. The student was required to master the *artes liberales*, consisting of grammar, logic and rhetoric (the *trivium*) and arithmetic, geometry, astronomy and music (the *quadrivium*). Medieval students didn't need a college education to shape their moral character, they already knew what was morally right and wrong. The society in which they lived was rigidly constrained by the ethical norms of Catholic Christianity. It was the church that molded their character and proscribed their behavior. Ethics and morals were, in essence, exactly what their etymologies implied, custom and habit. They required no further college coursework.

The protestant reformation of the 16th century, the enlightenment of the 17th and 18th centuries and the industrial revolution of the 19th century tore apart the unified Christian culture and reshaped the Liberal Arts. Revelation was replaced by scientific reason and the Christian ethic lost its role as the sole guide to moral behavior.

In the United States the job of moral education fell to the schools. Renaissance humanism and puritan intellectualism led to the belief that the purpose of education was to mold students into enlightened, morally sound citizens and leaders. The model of American higher education was furnished by Harvard's program of a classical Liberal Arts education strengthened by ethics. Indeed, the fact that so many private colleges in America were originally church affiliated, made the strong ethical component in our educational system a natural occurrence.

By the late 50's and early 60's, however, the diverse religious and ethnic backgrounds of a growing body of college students made the disappearance of ethical education from our colleges and universities almost a foregone conclusion. Indeed, by the late 50's the notion of a College as the source of an ethical education had so diminished, that Vassar's president, Sarah Gibson Blanding, made front page headlines when she addressed the women at Vassar on proper sexual mores. A survey of college catalogues conducted by the Hastings Center in 1977 and 1978 (2) indicated a singular dearth of courses dealing with ethics in any way at all, even though some colleges still professed in introductory paragraphs to be concerned with the ethical development of their students.

Although a formal catalogue survey has not, to my knowledge, been recently undertaken, I have a sense that it would be revealing. My contact with colleges that have STS programs as well as with colleagues in science departments convinces me that an increasing number of courses deal openly with ethical issues, particularly those that derive from science and technology. Courses like "bioethics," are now a part of the biology curriculum at many institutions. The most amazing part of this resurgence in the teaching of ethics is that it is prompted by developments in science and technology and it is being done by science teachers in science departments. While one would normally expect the departments of philosophy and religion to be at the forefront of ethical instruction, the offerings in those departments are more likely to deal with theories of ethical behavior, sometimes called "metaethics"; courses dealing with the particular issues and situations that are so troubling to our society are to be found in the departments one would least suspect of harboring them.

Why are science and technology so often at the heart of the most disturbing social issues of our times? There is a fundamental difference between science and technology which leads to differences in the ethical issues they tend to raise. At the same time, there is a similarity between them, which is why they both do tend to raise such issues. First, the difference. Simply stated, science is "knowing," technology is "doing." Scientists are searching (in a very special way) for knowledge of physical reality that will assist them in ascribing an order to nature that can be simply expressed in terms of laws and theories. Technology, on the other hand, consists of all the methods, processes and products for achieving a particular end. Nuclear power is a particular technology for achieving a sufficiency of usable energy, government is a technology for achieving control over society. Although we are usually concerned with technologies that require the use of scientific knowledge, such technologies are, in fact, of recent origin. Given this basic difference between science and technology, it is not surprising that ethical issues arising out of science are concerned with the good and evil of knowledge and the methods of obtaining it, whereas issues arising out of technology tend to be associated with the uses to which we put knowledge, the good and evil of our ends and the methods we use to achieve these ends. It is easy (although incorrect) to claim that science is value free, since knowledge, in itself, seems neither good nor evil. Technology, on the other hand, does not have this supposed purity of science and one seldom argues that it is value free. The neurobiologist, Gunther Stent, was once asked to state the most unethical thing that science could do. His response was: to search for the soul. If science set about to search for the soul, Stent explained, it most certainly would not find it; the conclusion that people would reach would be that the soul did not exist. This would be a disaster for society of an uncalculable magnitude. The search is unethical because science cannot find the soul by its methods. When religious groups ask science to define the moment life begins so they can deduce when abortion becomes a crime, they are effectively asking science to search for the soul.

The similarity between science and technology is that they both serve the community, i.e. society. Whereas ethics and morals are guides for individual behavior, the goals and methods of both science and technology are inherently community oriented and meant to serve the community. The authority of science and technology is communal welfare, the authority of morality is individual perfection. There has always been a fundamental opposition between the notion of man as a moral agent deriving authority from "ultimate values" and the notion of man as a social animal whose actions are induced by communal welfare (3). This opposition is at the heart of many ethical conflicts that result from science and technology. It is essential, therefore, that the educated person fully understand the goals and limitations of science and technology, not that such understanding will dissipate the tension between individual morality and community welfare, but because it will indicate where the tension is. Does a question such as "ought we employ a technology that is not risk free?" even have an answer, since the technical use of "risk" involves a statistical analysis over large populations, whereas the "common" use of risk implies the potential for harming an individual.

Science courses tend to be taught by people who are interested in the processes and products of science and technology, but are not necessarily as interested in their social ramifications. Social science courses are taught by those interested in the behavior of individuals and societies, but these teachers often lack scientific and technical expertise. STS courses, on the other hand, are designed to address precisely those issues that are at the interface between science and technology on the one hand and society on the other. Often, they are team taught, which brings two or more disciplinary perspectives to bear on a single theme. The introduction of ethical issues in these courses cannot lead to an accusation that time is being taken away from other necessities, since these issues are the necessities. My own experience with team taught STS courses has indicated that two teachers can delve more deeply into issues than one. Perhaps they dig with differently shaped shovels, so that one can get around the rocks that are uncovered and dislodged by the other. Examining the totality of an ethical issue, particularly at an introductory level, should not be done "incidentally" in the context of a science course, but should be done as part of a course designed to treat topics with ethical implications. Vassar's STS program approaches such topics through an introductory sequence of four separate one-semester courses that are grouped together under a thematic title, "Dilemmas of Technological Society." The courses are: Genetic Engineering, Basic Principles and Ethical Questions; Technology and Global Issues; Social Issues in Computing; and Technology, Disability and Public Policy. I like to think that these are the courses that would have been taught in the departments of Biology, Political Science, Computer Science and Sociology of the Harvard of years ago.

Of course, very few Vassar students (if any) will take more than one of these courses and many will take none of them. Yet it is encouraging that they are fully enrolled. Any course in the sequence provides a good indication of the variety of ethical issues that flow out of science and technology in general as well as some insight into issues that are peculiar to a particular technology. While I am convinced that it should not be a goal of STS courses to make students into more ethical people, I would at least want them to recognize ethical issues when they arise and to realize that the ethical component of an issue requires and deserves as thorough an analysis as the scientific and technical component.

It might be argued that even STS courses run the risk of having faculty who are not trained in ethics present students with difficult ethical issues. There is always the fear that, even with the best of intentions, instruction can become indoctrination and that students will not be given the critical skills in ethical analysis to cope with the moral opinions that are being urged upon them. This is not an easy problem to deal with and I can only suggest that team teaching and having an entire course in which to present a wide range of issues will tend to mitigate against such narrowness. The STS program is no panacea, but it is a very special kind of forum that is gaining the respect of more and more faculty and students. As it achieves an increasing legitimation, the issues it deals with share that legitimation.

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VALUES AND ETHICS IN STS EDUCATION: A CASE FOR SCIENCE FICTION

Joseph Marchesani and Carl Frankel

Like so many who attended the Technological Literacy Conference, we came to STS because we wanted to bridge the gap between the "two cultures." At Penn State, where we teach, that gap has been institutionalized: all of our academic units and programs are categorized as either "technical" or "non-technical." Our students mold themselves to that division.

Like other participants at the conference, we see STS as a means for challenging that division. A course in STS allows us to sensitize our science and engineering majors to the human implications of their fields: the ethics, the social implications, the value judgments that inhere in technological decision-making. At the same time, it allows us to pare away some of the specialist mystique that can estrange our non-technical students. For students in business or the liberal arts, it can help to reconnect them with the decision-making that repeatedly reshapes their lives and expectations.

In the introductory STS course that we offer, we have embodied these concerns in several specific objectives:

(1) to provide a sample of technical information for a non-specialist on topics like bio-engineering, cybernetics, environmental preservation, and nuclear proliferation;

(2) to encourage in both technical and non-technical students an understanding that the critical issues lie not in the knowledge bases of science and technology but in the decision-making that exploits those bases;

(3) to enable all of our students to anticipate their futures more credibly by laying out their responsibility in this process of decision-making.

We have recognized from the start, of course, that these objectives are ambitious -- more so, perhaps, because we are dealing with freshmen and sophomores. To increase our chances for success in attaining these goals, we recognized the need to make them less intimidating and more palatable for our students. Almost from the outset, we determined that we could do so with an intelligent selection of science fiction.

Obviously, we are not talking about those paranoid fantasies in which bug-eyed monsters from planet Zircon waste the landscape and ravage helpless humans, stereotypically female. However interesting from the perspective of popular culture, such works rarely address the physics of inter-stellar propulsion, the intricasies of planetary ecology, or the biology of interspecies breeding. Although the genre has left us with a lurid hoard of such stuff, much SF rises above the level of xenophobic pulp. In fact, science fiction has already accumulated a substantial number of works in which the science is credible, even when it has been extrapolated. Moreover, many of these works provide a valuable matrix of ethical and social considerations along with their scientific or technical information.

Over several years, therefore, we have experimented with ways of incorporating science fiction into our STS syllabus. All of these efforts have included short stories or novels keyed to the particular issues treated in our course. Typically, we organize the course around four issues like those cited earlier: environmental preservation, cybernetics, bio-engineering, and nuclear proliferation. As we take up an issue, we provide a necessary minimum of technical or scientific information, followed by a look at the ethical or social implications. After priming our students in this way, we then turn to a science fiction "laboratory," in which the significant variables are the ethical and social conflicts that the writers present and the decision-making involved in addressing these conflicts. In the most recent version of the course, we have also used writing assignments to extend and reinforce our students' interaction with the texts.

Two examples may help to clarify how this process works.

In our unit on environmental preservation, for instance, we have found Ernest Callenbach's Ecotopia to be particularly useful. It offers the students a detailed scheme in which American society has been reorganized to foster ecological balance, what the Ecotopians call a "stable state." In the book, Callenbach looks at the implications of such thinking as it applies to industry, education, medicine, recreation, and other major elements of our culture. In each, we confront the choices that are implied in our present lifestyle and those that would be required for a more protective interaction with the environment.

In the writing assignment, we asked our students to contrast the idea of "progress" embedded in American culture now, with the alternative expressed in Ecotopian values. Both the reading and the writing, we believe, helped to focus our students' thinking on environmental preservation. Furthermore, a more direct project for this issue would have had to be more narrowly focused, whereas their interaction with this fiction allowed them to imagine the implications more fully across a wider range of human experience.

For another unit of the course, one on nuclear proliferation, we selected Russell Hoban's Riddley Walker. The text is challenging in its language and its themes. Hoban assumes that his characters -- distant descendants of an age that demolished its technological culture with a nuclear war -- speak an English as removed from our own as ours is from Chaucer's. Within that transformed language, technological awareness survives as an ambiguous mythology, nostalgic for past power, but fearfully aware of past destruction.

Hoban focuses his plot on the effort -- successful but fatal -- to recover the craft of making gunpowder. As the title character wrestles with the interpretation of his culture's mythology, therefore, he is forced to make a series of decisions about the recovery of a powerful product from a mostly lost technology.

For the issue of nuclear proliferation, Hoban's book offers several approaches for student consideration. Its vision of a world struggling for centuries to recover from a nuclear war provides the obvious warning about the threat such weapons pose. In the predicament faced by Riddley Walker himself, it exposed the difficult decision-making, the social process, at the very core of this problematic technology. Moreover, the transformed language reinforces these themes by immersing the students in a world that has been profoundly estranged from our own, a world in which so much of our technological information has been irredeemably lost.

In these ways, Riddley Walker invites our students to focus on a threatening issue hedged with popular fear and complex, occluded information. As we found with Ecotopia, it enables them to interact imaginatively with an experience that we cannot realize more directly.

Our experience with science fiction leads us to recommend its use in STS courses in high schools as well as colleges. We believe it engages our students through their imaginations in ways that complement the presentation of technical information and more narrowly focused case studies. With a careful selection of works, we can use its technically informed scenarios to address significant ethical and social decisions. And because its appeal can extend to all students, whether their interests are technical or non-technical, we believe that science fiction offers a valuable tool for enabling STS to bridge the gap dividing the two cultures.

Selected List of Science Fiction Titles Used in STS 200, by Topic

Environment
Ecotopia by Ernest Callenbach
The Sheep Look Up by John Brunner
"Sundance" by Robert Silverberg

Cybernetics
"Fondly Fahrenheit" by Alfred Bester
Gateway by Frederick Pohl
"I Have No Mouth, and I Must Scream" by Harlan Ellison
Neuromancer by William Gibson
"Reason" by Isaac Asimov
"Who Can Replace a Man?" by Brian Aldiss

Bio-Engineering
Blood Music by Greg Bear
"Day Million" by Frederik Pohl
Hellstrom's Hive by Frank Herbert
"The Jigsaw Man" by Larry Niven
Man Plus by Frederick Pohl
"Masks" by Damon Knight

Nuclear Proliferation
"The Big Flash" by Norman Spinrad
A Canticle for Leibowitz by Walter Miller
Riddley Walker by Russell Hoban
"The Terminal Beach" by J.G. Ballard
"Thunder and Roses" by Theodore Sturgeon

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TECHNOLOGY AND GOD - TRANSCENDENT AND IMMANENT

Thomas M. King, S.J.

There is currently a dualistic image to tell of the mind-body relationship: the ghost in the machine. But with the rise in technology some people have claimed this dualism is vanishing, for the machine is consuming the ghost. Mind itself has become a machine. Simone de Beauvoir - the existentialist author - wrote an extended account of her mother's death. She terms the death "something as violent and senseless as an engine stopping in the middle of the sky." The image highlights the way technology can dominate the human perspective; it effects even the way we regard those we love. We begin seeing everything and everyone in terms of their function. Accordingly, many novelists and poets have warned us of the mechanization of human life.

But one of the most telling critiques of technology has come from the theologian and social critic, Jacques Ellul - whose message we have just heard via satellite. Ellul's 1954 study of technological society saw both science and the scientist serving technology: families are broken apart, people and nations are rearranged in the service of the vast international, productive machine, "La technique." Our ways of life are disrupted by technology, but the disruption is most evident in the "developing nations" where age-old ways of human living are rapidly giving way to the demands of the modern world. But in speaking of the demands of the modern world one must ask, who makes these demands? Ellul would answer that it is la technique acting with a will of its own. His analysis is vivid and powerful, and his conclusions are deeply pessimistic.

The Family, the Arts and Religion have long served as places of personal refuge apart from technological society. They have traditionally been areas where ghostly realities - spiritual and personal - could be reaffirmed and our humanity restored. But Ellul would have it that these areas are being eliminated by the impersonal technological advance - an advance that we call the development of nations or even call progress. And what understanding can be gained from theology?

There is a sense in which any human thought about God will include a reflection of the human thinker. That is, any theology will offer an image of the human scene. When there were kings and lords, God was said to be King and Lord; when there were judges, God was said to be the ultimate Judge. Accordingly, "man the maker," the human being as tool maker, homo faber, has tended to see God as ultimate maker, the Deus faber in the sky. Recently a new form of natural theology has developed among some scientists (those who work with the Anthropic Principle). These scientists would argue that a higher intelligence must have planned the coupling constants of physics in such a way that eventually the universe would give rise to life. Thus God is seen as design Engineer. Edward Friedkin, the computer whiz, would see God as the great Programmer. They are suitable images of God for a technological age.

But the image of God making the world has been around for some time. What is new is that part of the image has been forgotten: in the Judeo-Christian tradition after God worked six days in making the world, he rested on the seventh. Accordingly, the human being was also to rest on the Sabbath. This tradition was widely observed for centuries, but recently it has given way to the "demands of the modern world." The day of rest baffles technocratic man. He or she feels altogether worthless if not producing! The day of rest was long able to remind our ancestors that they were more than their function. We should recall that the survival demands of the ancient world were more severe than the survival demands of today, yet even then a day was set aside to remind people that they were more than what they produced. On the Sabbath day God was to be praised simply "because of his great Glory" - the very phrase makes no sense in a functional world. But that is why it is needed now more than ever.

Above I have argued that theology always reflects the human scene. If today we find God seems to be a vanishing Ghost in the modern world, perhaps it is because we ourselves are vanishing ghosts before the onrushing machine we have made.

But suppose we shift this engineering picture to consider a different line of thinkers, biologists, men like J.B.S. Haldane, Julian Huxley, Lewis Thomas, Pierre Teilhard de Chardin and those who support what James Lovelock has termed the "Gaia hypothesis." All of these thinkers would maintain that we are not manipulating an alien world of technology or that an alien world of technology is not manipulating us. Their "biological" world-view would look for organic relationships and reject the dualism implicit in the ghost and machine; there is a symbiosis that this extrinsicist image does not allow. And these thinkers have applied their way of thinking to the planet as a whole. They regard the planet as a single organism in process of formation; within this organism human individuals resemble cells within a body.

But, once, again, if theology reflects the human scene, how would such a view of the human scene speak of God? It is evident: just as I am the soul that animates by body, God is the World Soul animating the planet. Thus, it is not the technological God who made a world extrinsic to his or her own self; it is the immanent God who is found within the world. God is not the design Engineer, the distant Ghost that constructed the world machine. God is the Soul animating all events, the single Identity pervading and softening all things. It is the God within of Rene Dubos. But how would this sound in Christian terms? St. Paul speaks of Christ as the one "in whom all things hold together." (Col I,17) Does not that phrase suggest that Christ is the unifying Soul of the world? St. Paul speaks of Christ's Body as including all things so that eventually God will be "all things in all things." These phrases can sound strange to many Christians, yet they are part of our Scriptures. They do not reject the earlier image, for the Bible does indeed present God the Maker, an image abundantly developed in Christian history. But most Christians have overlooked the Pauline images that suggest a common soul within the world.

St. Paul wrote to the Galatians: "I live, now not I, but Christ lives in me." It is a personal statement that tells of an immanent God, a God within. But could we not take the phrase - "I live, now not I, but Christ lives in me" - and conceive of ourselves as cells within a wider organism. And just as the cells of our body might have a sense of themselves as individuals and also a sense of sharing in a deeper and common identity, are we not likewise aware that we share in a common human identity. And has not the technological development of the earth played an important role in developing this awareness? Perhaps we sense that we are being drawn on by a momentum that far transcends our individual lives. But could it not be that the cells of our body have a similar sense? Then who might the presence be that we sense behind "the demands of the modern world?" Might not there be a common soul forming itself through human development? As some of you might know, this line of thought has been developed at length by the Jesuit geologist, Pierre Teilhard de Chardin.

I would end by making two recommendations:

1. The first concerns the immanence of God: Christians should follow St. Paul and develop a sense of God pervading the material world and animating it as a soul animates a body.

2. The second concerns the transcendence of God: Christians and Jews should restore the observance of the Sabbath. This would allow us to recognize that the being of God transcends the technology of his works, and that we who are made to his image do the same.

Following these recommendations, believers can share in the technological world without feeling they or their God are vanishing ghosts before an onrushing machine.

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THE RELIGIOUS PERSPECTIVE IN STS

Lynn A. Brant and Carol Hilton

Science is primarily a method by which humans can investigate the physical universe. Because science is a dynamic activity, the body of knowledge and understanding it creates is always changing. There is also an institutional aspect to science. Thousands of men and women, working in the labs and classrooms of universities, government agencies, and private corporations around the world which are supported by billions of dollars each year make science a powerful economic and political force. Science, and the technology it fosters, drives many of the changes that occur in modern industrialized societies. Science is not an isolated activity operating separately from the rest of society, but is an enterprise that is intimately connected to all other aspects of the social milieu. It does not, indeed cannot, exist isolated from the political, social, and economic conditions of our times.

New scientific paradigms have given birth to waves of new ideas and views across all human thinking. In the history of science, there has been much entanglement of scientific learning with religious dogma and the associated political power. Learning and intellectual enlightenment of all kinds had to become secularized in order to escape the control of the church and state because scientific theories and discoveries challenged the world views of these power structures by altering ideas of what it meant to be human and the nature of reality.

As an enterprise, science wields power that can disturb or support powerful interests in the modern society. Although it is essential that the integrity of the scientific process be guarded, it is difficult to keep science from becoming entangled in modern power structures. Although most scientists earn their living by pursuing goals set by business, military, or political objectives, a continuing deep)seated fear of religion's influence in science (which is partly historical and partly from modern versions of pseudoscience) has caused the scientific community to distance itself from a religious perspective. But the inherent character of science does not permit it to be reflective and responsible. It has no way of making the very important distinction between the possible (what can be done) and the desirable (what should be done). Along with many desirable results, science and technoloy have produced social and environmental problems that may overwhelm us. Is there a place in the scientific enterprise for values and wisdom coming out of a religious perspective that is compatible with science and which would further the highest goals of humankind by helping make the desirable (what should be done) decisions? If so, where might we look for this perspective?

We suggest that the answer may lie in a new world view created by science itself. Within this century, much has been learned about the functioning of systems that maintain life on this planet. Not only have the extant members of the living system been studied more closely, but all aspects of the earth and its history have come under scrutiny. What we have learned is that it all connects in a great interdependent system which is constantly changing. Perturbation of any part causes change in all the parts. Humans as well as natural events can alter the systems. To understand how it all works requires a holistic perspective.

Earlier in the twentieth century, a similar view of the universe was proposed by Alfred North Whitehead. Whitehead, a mathematician, was also well grounded in the liberal arts. As he pondered world history and the revelations of late 19th and early 20th century science he developed a body of thought in which he viewed the universe as being one highly interconnected whole. His main idea was that the total history of the planet could be explained in terms of interrelated, interacting, and interdependent factors; forming a kind of web or system. Each "event" is multi-faceted and acting upon and being acted upon by other events; each with its own history, its own present, and its own contribution to the future. No event occurs in isolation. He found this systems approach could be supported by all branches of science and even in studies of human endeavors.

Among religious thinkers, Whitehead's systems approach is called "process theology". They see that human beings are very much a part of the larger system. As sentient beings, humans can alter the system more than any other life forms. To be human is to be a part of the system and to make an impact upon it, but the nature and magnitude of those impacts should be of concern to a responsible populace.

Because the life support systems are so interconnected, and the power of our science and technology is so great, unintentional and unwanted effects of human activities that result from our lack of understanding are no longer limited to small areas of the earth. These impacts are now global in extent. Humans are now discovering that we may have already set into motion changes in the life support system that may be extremely harmful.

Process theology is a religious perspective which complements the scientific view of an evolving, changing universe. It generally incorporates new knowledge rather than maintaining a rigid set of dogma. It does not make a religion of science; rather, process theology is informed by science. We think process theology works in the guidance of science because it incorporates both scientific knowledge and the traditional questions and concerns of religion.

The time has come to end the conflict between the religious and the scientific world views; to cease the perpetuation of the myth that there is a built-in disparity between these two branches of human concern. Both need each other. Both are part of the cultural milieu and must be acknowledged as such.

Human survival seems to depend on the scientific and technological community becoming responsible to the rest of society. Scientists and technicians are part of the human and planetary ecological system. We are all part of the process; the problem as well as the possible solution. If we are to survive and further the most worthy goals of humanity, we must apply our human abilities within a holistic approach, rather than the single-minded and narrowly-focused approach so commom up until now. We must incorporate all human knowledge and concern into the process of which we are a part.

In this paper, we have attempted to speak of the religious not in terms of one orthodoxy or another, but as an outlook which values the wonder and ultimate mystery of the universe. Regardless of refinements of technique within science and technology, we believe humans will never fully understand the universe. A religious view within science and technology can help guide these endeavors toward desirable ends. The systems approach insists that the education of scientists include a holistic perspective on science itself as well as the impact of science on society. The religious perspective we have advocated in this paper is one way of doing it.

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COMPUTER LITERACY EDUCATION

Ronni Rosenberg

Introduction

Computing is the predominant technology of this age, and transactions with computers are part of daily life. Decisions about how computers should – and should not – be used will be made increasingly by graduates of an educational system that incorporates "computer literacy" as a fundamental component. The wisdom of these decisions will depend largely on the quality of that education. In this paper, I describe a study of the phenomenon of computer literacy in primary and secondary schools, informed by the perspectives of both education professionals and computer professionals.

Computing in schools has spread rapidly. In a survey conducted in November 1985, 96% of the respondents – primarily classroom teachers, computer coordinators, and administrators – said that their schools offered instruction in computer literacy.[1] The most detailed study to date of microcomputer use in schools found that as of spring 1985, 86% of U.S. schools had at least one computer for instruction.[2] All surveys of computers in schools reveal steady increases over the past few years in the number of computers per school, percentage of students who use computers, and amount of time students spend using computers.

Yet, the frenzy of equipment purchases and curriculum changes takes place in an atmosphere devoid of critical evaluation of how and why computer literacy is taught. Moreover, there is little involvement in these educational changes by people who are already computer literate: computer professionals.

Research Plan

Against the widespread background of optimism for school computerization, my goal is to assess computer-literacy education in a study that differs from previous work in two ways. First, it is informed by the perspectives of not only education professionals, but also computer professionals, the most computer literate group in society. Second, it takes a *critical* look at computer literacy, seeking justification for claims about the benefits of computers in schools.

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[1] "Reader's Survey Results: What Is Computer Literacy?" *Classroom Computer Learning* (March 1986) 53.

[2] Henry Jay Becker, project director, "Instructional Uses of School Computers," Issue No. 1 (June 1986), 2. Center for Social Organization of Schools, The Johns Hopkins University, Baltimore, Maryland.

The key question is: What is behind all the attention to computer literacy in schools? Many other questions follow:

- What is the state of computer literacy in schools with respect to curriculum, hardware, software, training, support, etc?
- School budgets and class days are finite and strained. Basic education is under attack, but money and time are found for computers. What must schools give up to fit in computer literacy; what are the hidden costs of computer-literacy education?
- Why is computer literacy taught? Are the reasons justified? What drives the perceived need for computer literacy in schools – educational goals, available technology, computer manufacturers' advertisements, media hype, labor market needs? Can computers contribute to education in meaningful ways?
- Is society well served if schools concentrate on information access (which computers can facilitate), not information analysis (which has nothing essential to do with computation) or the other critical skills that do not depend on information at all?
- How differently are all these issues perceived by educators and computer technologists?

To explore these questions, I collected data from several sources. I read the computer-literacy literature, from academic papers to popular articles to classroom materials, by educators and computer professionals. I observed primary/secondary classes, graduate classes (for teachers, administrators, and computer coordinators), and other educational uses of computers in additional schools. I surveyed computer-literacy teachers in a graduate class. And I interviewed teachers and computer coordinators and had many discussions with computer scientists, in the course of years of working and studying in the computer industry

Computer Environments in Schools

Computer literacy, defined in a variety of ways, is becoming a standard part of primary/secondary school curriculums in the U.S. Computer classes are added to schools as fast as money to buy computers can be squeezed from strained school budgets (in some cases, even faster, as some schools decide to teach computer classes although they cannot afford to buy computers).

Most of the teachers I interviewed recite a litany of problems with computers in their schools, starting with not enough equipment. Investments in hardware that are large by school standards brought the typical school (K-12) to a ratio of only one computer for every 40 students (as of April 1986, when the last large-scale survey was done.)[3] The ratio is improving slowly; the rate of school computer purchases appears to have slowed down. The fuss about computers in schools centers around the impact of a machine to which students have very little access.

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[3] William J. Ridley and H. Hull McAllister, Jr., "Transforming American Education: Reducing the Risk to the Nation. A Report to the Secretary of Education, United States Department of Education, by the National Task Force on Educational Technology" (Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement, April 1986) 11.

The problem of too little hardware is compounded by the problem of inadequate hardware. Most computers that students use in school are at the cheap end of the personal-computer spectrum. These small machines are extremely limited; for instance, in the length of document that they can allow students to write. One prominent computer scientist calls this "kindergarten-level training" in computers.[4]

Most "educational" software is denounced widely by educators as not satisfying curriculum needs. Their claim is supported by a study of computer-literacy tests given to over 3,000 students at 3 grade levels in 115 schools. Test questions were based on instructional objectives from computer-education curricula. Students trained with computer-literacy software averaged only 50% correct in all grades.[5] Many students (and teachers) get bored with the drill-and-practice software to which most of the computer time in elementary schools is devoted.[6]

Schools that find money to buy computers often cannot afford to make accompanying investments in software, maintenance, and teacher training, and continued investments in new hardware (computers become obsolete quickly). It is not in the interest of computer sellers to emphasize the high cost of support. In one school, teacher training was one hour of instruction by a local Radio Shack store, provided free with the school's purchase of Radio Shack computers. There are entire school districts that have no one with significant computer training. Some districts have mandated computer curriculums and no computer coordinator, or mandated curriculums and no funds allocated for computing. Even people with the title "computer coordinator" are trained in fields other than computing.

Teachers who become convinced that students should learn about computers make heroic efforts to educate themselves with information from school resources and friends. They are lucky if they stay a small step ahead of their students. Their perseverance in computing environments that they label inadequate suggests that school computing is *technology-driven*, not education-driven.

Despite its problems, the present environment of school computing has been achieved only at great cost, relative to strained school budgets. As early as 1983, money spent on software and hardware in schools totaled one-third of all money spent on books in all subject areas and all grades.[7] More money for computers means less money for teacher salaries, continuing teacher education, classroom aides, books and other materials, building maintenance, office equipment, etc. Are these tradeoffs justified?

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[4] Daniel D. McCracken, "A Skeptical View of Computer Literacy," *SIGCSE Bulletin*, 16, 1 (February 1984) Appendix A, *Proceedings 15th ACM SIGCSE Technical Symposium on Computer Science Education*, 5.

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[6] Art Levine, "Something doesn't quite compute," *U.S. News & World Report*, 101, 19 (10 November 1986) 78.

[7] Henry Jay Becker, "Computers in Schools Today: Some Basic Considerations," *American Journal of Education*, 93, 1 (November 1984) 22.

Evaluation of Educational Computing

The education literature is wildly optimistic about computers. "Computer skills" appears on some educators' short lists of basics, along with reading/comprehension and communications skills. The assumption that everyone needs to know about computers to function today is widespread among educators. Despite acknowledged problems, there is much momentum to increase school computer use.

The enthusiasm about computers that infects the education literature is almost uniformly uncritical. Most papers describe the format of a class or piece of software, with little evaluation. The assumption that computer education is worthwhile, even essential, is rarely challenged. Many articles assert benefits of computer literacy with no justification whatsoever. The benefits of school computing usually are expressed in the future tense. There always seems to be a technical reason (e.g., not enough machines) why these benefits have not yet been achieved.

One prevalent assertion is that computer programming improves general thinking abilities. One educator writes that computer-literacy classes should include instruction in programming, because "...the logic and problem solving skills learned are invaluable."[8] Another writes: "Programming can serve this purpose [of increasing problem-solving and logic skills] well. It encourages, even demands, logical reasoning. It sharpens problem-solving abilities ...."[9] A few people argue that the skills students really need to adapt to their world are not computer skills, but skills in learning, communicating, organizing, and planning. But most also accept without question that everyone should know about computers: "We should know how to do a little programming and should understand something about the theories of computing. We should certainly engage ourselves in the marvelous problem-solving potential of computer technology and can only benefit from learning how to represent abstract ideas in concrete form."[10]

Along with continued uncritical acceptance among educators of the need to add computer literacy to school curriculums is a continued absence of the computing community in evaluating and participating in computer-literacy education. Development of new machines and software emphasizes commercial profit, not educational value. Computer-science research in "computers and education" emphasizes new concepts, laboratory prototypes, and impractical visions, not what goes on in schools (especially at levels below undergraduate). Like most professions, computing is not motivated from within to consider questions that might threaten its enterprise, such as critical questions about the value of computers in schools.

Schools themselves have no money to fund work in educational computing, to better ensure a good match between what technology can provide and what teachers need. Relatively poor educational systems cannot compete with commercial and military organizations for the skills of trained computer professionals. Educators know little about what the computing profession thinks should be taught as computer literacy. And computer professionals, the most computer-literate group, know little about what is being taught as computer literacy; academic training in computing includes nothing about computers in education. A few are involved in volunteer committees that advise a school on which machines to buy, but analysis of the decision to teach computer literacy is not part of such committees' work.

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[8] Jane M. Fritz, "Rethinking Computer Literacy," in Karen Duncan and Diana Harris, eds., **Computers in Education**, New York: IFIP (1985) *Proceedings IFIP TC3 4th World Conference on Computers in Education - WCCE 85*, 707.

[9] Alan Neibauer, "The Computer Literacy Myth," *T.H.E. Journal* (February 1985) 90.

[10] Roger Robin Ekins, "Computer Illiterate, and Proud of It," *AACJC Journal* (October/November 1985) 31.

The few computer scientists who write about computer-literacy education feel that the typical school computing environment is too poor to support worthwhile education. Among other problems, they cite hardware that is unreasonably simple, small, and outdated, and software that is simplistic and hard to use (often because the machines they run on are so limited). One leading computer scientist calls computer-literacy education "kindergarten-level training," soon to be obsolete.[11] Alan Kay, a seminal researcher on easy-to-use personal computers, says that the typical school approach of learning about computers by emphasizing how to get things to run is like learning language by emphasizing how to recognize words and books. The flaw in such education is too much emphasis on mechanics and not enough on higher-level content.[12] Some educators agree: the principal of a K-12 school in North Carolina believes that computer applications, not mechanics, should be taught, and only on a "need to know" basis.

I spoke with a Harvard professor of introductory computer science, whose students include many graduates of the best school systems in the country. Most of them had prior exposure to computers, and he had this to say about their preparation: "Secondary school education is doing nothing for these people. They don't know anything about computers. It's a waste of time." He finds that these students have no intellectual advantage over other students who had never used a computer.

What is Taught as Computer Literacy

Computer-literacy classes typically include some subset of these topics:

- an overview of hardware components and how to operate and handle them,
- a few basic software concepts,
- three applications (word processing, spreadsheets, and databases),
- a smattering of programming in either Logo (which is not used outside of schools) or BASIC (the most widely used computer language in schools, but denounced by many computer scientists), and perhaps
- a brief, superficial mention of "social implications"

Computer-literacy classes have unclear goals. Some commentators essentially give up on defining "computer literacy," by defining it as "whatever one needs to know about computers":

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[11] McCracken, 5.

[12] Alan Kay, "Computer Software," *Scientific American*, 251, 3 (September 1984) 59.

> "The MECC [Computer Literacy Study] authors responded that computer literacy is whatever knowledge and skills the average citizen needs to know about computers ...."[13]
>
> "[T]he National Center for Educational Statistics (1983) assembled a panel of experts to define this elusive concept and guide subsequent national survey work. The ten-member panel settled on the following: 'Computer literacy may defined as whatever a person needs to know and do with computers in order to function competently in our information-based society.'"[14]

It is stated often that students should be taught general concepts, but most computer-literacy course descriptions emphasize particular machines, programs, and languages, and it is only in these specific terms that teachers are trained (if at all). These machines and software quickly become technically obsolete.

The goal of students taking these classes is expressed vaguely: "knowing how to use a computer" or "running a program." Goals that sound important on paper may translate in the classroom into mechanical skills: "knowing how to use a computer" may be manipulating floppy disks and a printer, and "running programs" may be operating a basic application program, with no understanding of the underlying machine or any general computing concepts.

Teachers may figure reasonably that if their students learn as much about computers as they know themselves, the students are computer literate, but teachers usually get minimal training in computers. Some information that is presented is simply wrong. In one class, a computer operating system was defined incorrectly as a program that "directs the flow of electricity." This was a graduate class in computer literacy, taught for teachers, who went forth with fundamental misconceptions about how computers work.

In some cases, common misconceptions are presented as fact, even in textbooks. One book teaches that computers work with numbers.[15] This entirely misses the point that computers derive most of their power from their ability to process abstract *symbols.* Most computers spend little time "crunching" numbers.

Inaccurate classroom materials nurture inaccurate models of computing. When the Bank Street College of Education studied one computer-rich school, they found that students had incorrect models of the inner workings of computers and the powers and limits of computers, and students did not understand the fundamental notion of the computer as an abstract computational device.[16]

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[13] "Mission: Define Computer Literacy. The Illinois-Wisconsin ISACS Computer Coordinators' Committee on Computer Literacy Report (May 1985)," *The Computing Teacher* (November 1985) 10.

[14] Roy M. Gabriel, "Assessing Computer Literacy: A Validated Instrument and Empirical Results," *AEDS Journal*, 18, 3 (Spring 1985) 154.

[15] Jack L. Roberts, Scholastic Computing: An Introduction to Computers, Teacher's Edition (New York, NY: Scholastic Inc., 1984) 5.

In other cases, the level of explanation, while not inaccurate, is simplistic to the point of inaccuracy. On one computer-literacy test, the correct answer to the question "How does a computer solve a problem?" was "It follows instructions to do what it is programmed to do."[17] In classes I observed, this is exactly what students are taught: computers do (only) what they are told to do. Such simple statements nurture false models of computing when applied to large, real-world systems. In a class discussion of complex computer systems, students extrapolated from their class exposure to very simple programs and machines, to the belief that computer experts understand and control very complex systems. This is comforting but wrong; it disguises the subtler truth that many of the large programs we depend on are so complex that no one understands how the system of which they are a part functions. This level of explanation is necessary for informed decision-making about the uses and abuses of computers.

Most computer-literacy classes emphasize what is properly viewed as vocational education that prepares students for menial jobs by concentrating on the mechanics of operating machines, running applications, and learning jargon. This contrasts sharply with what computer-literacy teachers believe they are teaching, a "hidden curriculum" of general skills such as problem-solving, logical thinking, organization, and planning. As discussed below, there is no evidence to support these beliefs.

Reasons for Teaching Computer Literacy

The most common reasons for teaching computer literacy in schools are (1) computer job skills will be needed by everyone, (2) computing is good discipline for the mind, and (3) every informed citizen in today's society "must" know about computers. These reasons are widely accepted, but rarely does anyone offer – or demand! – justification for them. They do not stand up to close examination:

1. The Argument of Jobs

Labor-market studies predict more jobs in menial service areas, jobs that will require no knowledge of computers; indeed, jobs that require little or no training beyond high school.[18] "Recent research suggests that the number of high technology jobs is far fewer than most people think and that, contrary to popular belief, most jobs in the future will require little in the way of computer skills or awareness."[19] The trend in computing is toward machines that are easier to use, that require less and less "literacy" of users.

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[16] Ronald Mawby, et al., "Structured Interviews on Children's Conceptions of Computers," Technical Report No. 19, Center for Children and Technology, Bank Street College of Education (February 1984).

[17] Tina T. Cheng, Barbara Plake, and Dorothy Jo Stevens, "A Validation Study of the Computer Literacy Examination: Cognitive Aspect," *AEDS Journal*, 18, 3 (Spring 1985) 148.

[18] See U.S. Bureau of Labor Statistics, "Occupational Outlook Handbook, 1982-1983," Superintendent of Documents, Washington, DC: U.S. Government Printing Office, Bulletin No. 2200. Henry M. Levin and Russell W. Rumberger, Russell W., "The Educational Implications of High Technology," Project Report No. 83-A4, Institute for Research on Educational Finance and Governance, School of Education, Stanford University (February 1983) 6. Gene I. Macroff, "The Real Job Boom Is Likely to be Low-Tech," *New York Times* (4 September 1983) 16E. Langdon Winner, The Whale and the Reactor, Chicago: University of Chicago Press (1986) 106.

Most jobs that "use" computers require no general knowledge of computing; e.g., making airline reservations or using computerized cash registers. "Most jobs regarded as high technology positions are characterized by routine work, Mr. Kohl [economist, Communications Workers of America] said. Workers must have only a high school education and ability to pass minimum intelligence tests."[20] The contribution of genuine high-technology jobs to total employment growth is quite small: In 1984, for instance, programmers were only 0.5% of the workforce.[21]

Textbooks for computer-literacy classes assert that in the future, people without computer skills will be at a competitive disadvantage. However, surveys of large businesses indicate that the skills they want, but rarely find, in employees – written and oral communications skills and interpersonal skills – are unrelated to computers. A study by the Bell System showed that "its managers with liberal arts background possessed better administrative skills – organizing and planning, decision making and creativity – than their counterparts with business and engineering majors."[22]

2. The Argument of Mental Discipline

There is no evidence to support the claim that learning about computers fosters mental discipline or that whatever is acquired in computer classes transfers to other areas of learning. One study of the connection between learning to program and learning to think concludes: "Despite these claims [that teaching programming is a good vehicle for teaching thinking skills], there have been very few relevant research studies and almost no convincing support of this connection."[23] Another study found no difference between programmers (students who had spent time programming) and non-programmers, in several dimensions of planning that were considered. The researchers concluded that learning problem-solving skills is largely a *social* activity that is not supported by computers.[24] Informal observation of computer technologists gives no indication that they are "better" thinkers than any other group of people.

3. The Argument of Informed Citizens

Teacher training in computers is so limited, and most "educational" software is so bad, that computer classes may be doing *harm*, by turning out people whose model of computation is extremely simplistic but who nonetheless believe themselves to be "computer literate." A little of the wrong information masquerading as technological literacy could lead to dangerously unwise decisions about using computers. People whose education about computers is limited to tiny programs are not equipped to make informed decisions about the massive computer systems that run real applications. Such large systems are *qualitatively* different than the "toy" computers students encounter in computer-literacy classes.

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[19] Peter Kelman, "Computer Literacy: A Critical Re-Examination," *Computers in the Schools*, 1, 2 (Summer 1984) 5.

[20] W. Serrin, "Computers divide AT&T and its workers," *New York Times* (18 November 1983) 1.

[21] McCracken, 1.

[22] Ekins, 30-31.

[23] Richard E. Mayer, Jennifer L. Dyck, and William Vilberg, "Learning to Program and Learning to Think: What's the Connection?" *Communications of the ACM*, 29, 7 (July 1986) 605.

[24] Roy D. Pea and D. Midian Kurland, "Logo Programming and the Development of Planning Skills," Technical Report No. 16, Center for Children and Technology, Bank Street College of Education (March 1984).

4. Other Reasons

Many computers are already in many classrooms. Whether or not they were well justified originally, once they are in schools, they certainly will be used, and justifications will be sought for the expense of their purchase and upkeep. Some people say that parents *want* their children to learn about computers, and that is reason enough to teach computer literacy. They do not question the justification for parents' calls for computers. Are these calls influenced by computer-company advertisements that explicitly link good parenting with the purchase of computers? Are parents' calls for computers and media hype about computers simply fueling each other?

Others say that many students and teachers *like* computers, and that is reason enough to use computers in schools. They do not question the causes of interest in computers. If a teacher responds positively when given a new computer, is this a reflection of the educational value of computers, or the natural result of being treated to a much heralded tool, in an otherwise poor environment? Every school I visited lacked basic office equipment; most teachers I spoke with prepare lesson plans on mimeograph machines, because copiers are too expensive. Even in such environments, the fact is that most teachers do *not* respond with pleasure to shiny new computers; they complain of *pressure* to use computers, from parents and administrators. Computer coordinators and teachers who *are* interested in computers feel uncomfortable being in the minority; one told me this: "You don't find many technological optimists in schools. It's like pulling teeth to get people to use computers." Some teachers complain that students grow bored with the poor software, after the initial interest in the new machine wears off.

Computer-rich schools are treated to not only new equipment but extra attention. One afternoon in a Boston school, I watched 10 university researchers observe, videotape, audio-tape, transcribe, and photograph 2 primary-school students using computers. In an environment – the U.S. public school system – where 5,200 teachers are physically attacked by students each month,[25] is it surprising that people respond positively to admiring attention from the outside world?

Still other people agree that there is no good justification for computer-literacy education, but argue that the lack of justification should not be criticized, since computer literacy is no different – no *less* justified – than any other school topic. By failing to make informed, critical decisions about the uses of computers in schools, surely these advocates of computer-literacy education are demonstrating computer illiteracy!

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[25] Thomas L. Martin, Jr., "Intellectual Capital Formation and the Education System," National Academy of Engineering, *The Bridge*, 17, 3 (Fall 1987) 13.

Conclusions

Optimism about computing is the most recent manifestation of an old fascination with technology. Langdon Winner, a political historian, notes: "It is not uncommon for the advent of a new technology to provide an occasion for flights of utopian fancy. During the last two centuries the factory system, railroads, telephone, electricity, automobile, airplane, radio, television, and nuclear power have all figured prominently in the belief that a new and glorious age was about to begin."[26] Historically, society has been uncritical until later stages of the use of a new technology, when negative effects are all too obvious. The computing profession is notoriously guilty of overly optimistic claims. At last year's Technological Literacy conference, Richard Devon pointed out: "Typically, these claims for the importance of computers rest on prophecy rather than on analysis of the present. However, in retrospect, predictions for computers have not proven accurate."[27] The educational system too has repeatedly seen as its salvation the new technologies of other times – radio, film, closed-circuit television, programmed instruction, language labs – that now gather dust in school storage closets. Some teachers already suggest that computers soon will follow these other technologies into the closets.

Computers are tools that, when accompanied by good software such as well designed word processors or spreadsheets, can facilitate mechanical aspects of working with words and numbers. But most computers, and certainly the simple ones in schools, manipulate syntax, not semantics. While computers can help students with the mechanical tasks of retrieving data, processing words, formatting text, checking spelling, and revising text, they do not address the intellectual labor of analyzing information, generating ideas, and expressing thoughts clearly. Computer-literacy courses concentrate on low-level computer operation. If there is a hidden curriculum in such courses, it emphasizes form at the expense of content.[28]

It is tempting to believe that technology can solve tough social problems, human problems, from politics to education. But genuinely wise decision-making about computer use cannot be founded on existing "computer literacy," a conglomeration of bad software, run on outdated hardware, by poorly trained teachers, in unsupportive environments, with vague objectives. There is no justification for mandatory computer-literacy education as it is now taught – unrelated to the promise and problems of large-scale, real-world computing. Moreover, we should not allow the euphoria about computers in schools to become a smokescreen, diverting attention from fundamental educational problems – foremost of which is the lack of *real* literacy among many graduates – that may not have technological solutions.

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[26] Winner, 106.

[27] Richard F. Devon, "In Praise of Computer Illiteracy." *Bulletin of Science, Technology & Society*, 7, 1 & 2 (1987) 338. Presented at the Second National Conference on Technological Literacy, Washington, DC, 6-8 February 1987.

[28] See Ivan Illich, "Computer Literacy and the Cynernetic Dream," *Bulletin of Science, Technology & Society*, 7, 1 & 2 (1987) 307-308. Presented at the Second National Conference on Technological Literacy, Washington, DC, 6-8 February 1987.

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HUMANIZING THE NEW EDUCATION TECHNOLOGIES

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William F.X. Reynolds**

Think about the classroom as a technological system. Textbooks, blackboards, computers, computer programs, films and videotapes, and of course the teachers and learners, are elements in that system. The authors of this paper share a concern that new technologies are introduced to the educational marketplace with such enthusiasm that they often assume the aura of a technological fix, a panacea for the oft described crises in American education. If only there were enough computers and modems for students and/or teachers to interact on line or if only the video programs existed which could get across exactly the desired information and attitudes, our problems would all be solved. Critical analysis of the structure and operation of technological systems is a major theme of the STS community. Too often, the technological nature of learning systems such as the classroom, escapes this scrutiny. The "promise" of new technology continually invites us to streamline and automate, to opt for efficiency as defined on a high-tech productivity model and, in so doing, to lose touch with the human scale so important in the relation of student and teacher.

We argue and demonstrate, through our own experiences, that the most effective way to introduce new technologies such as computer conferencing and interactive video, and the most creative design of telecourses can and should be accomplished in such a way that this human scale is retained. This demands that educational goals and proven pedagogical approaches drive the technology rather than the other way around. It often requires that curriculum design and patterns of teacher/student and student/student interaction be developed on an ad hoc basis.

Additionally, it appears to us that the use of technology in a learning system threatens to become an end in itself. Driven either by the status that comes with pioneering in high- technology or by the pressure to justify expenditure of funds on sophisticated equipment, the temptation is strong to use whatever technology may be at hand at every opportunity.

In contrast, we have found that the most effective use of a new technology is often one which falls short of a total and complete application of it. Computer conferencing based learning systems often work better when they are combined with traditional face-to-face meetings. Videodiscs can sometimes serve better in a more rudimentary application than at the most sophisticated level of the technology.

The term "educational technology" is a misnomer created by the people whose job it is to sell computers and video equipment to academic institutions. What transforms an otherwise sterile machine into a truly educational device are the enduring pedagogical objectives and the proven techniques of motivation and inspiration which good teachers bring to every person-to-person learning experience. Consider the ultimate technological fix, plugging a computer cable into a student's head to input facts and attitudes. Education is more than the simple infusion of knowledge. Education is human activity. If we allow machines to make it otherwise, we are courting technological disaster.

New Jersey Institute of Technology has been actively involved in the application of state-of-the-art technologies to education: teleconferencing, interactive videodisc systems, creative design of telecourses, and more. These technologies have the potential to "revolutionize" education, as one can read in the promotional literature. They are used to their best though when they facilitate and enhance rather than replace sensitive human interaction. The eight contributors to this paper have sought to accomplish this each in his or her own way. They have adapted the technologies in ways that are true to their own teaching styles, letting their own personalities shine through.

Teleconferencing--The EIES Network

The Electronic Information Exchange System (EIES), a computerized conferencing network based at New Jersey Institute of Technology, links 2,000 people in the United States and foreign countries. The basic EIES system supports electronic messaging, conferencing, personal notebooks, text editing, and document preparation. Its advantages include participation at the site, time, and place of choice; interaction with a multitude of peers and experts; a printed transcript of the proceedings; and minimal costs compared with telephone, mail, and travel. Time and distance are minimized as barriers to personal interaction.

Teachers usually work in structured and relatively isolated environments. Conferencing offers them a new opportunity to reach out beyond their schools to other teachers and professionals. But such efforts are often undermined when proponents of technological systems simply put the machines in place and sit back to measure the results.

One project at NJIT illustrates how EIES, or any other computer conferencing system, can work when it is closely integrated into a broader effort in personal networking. The focal activity of the group is developing hands-on laboratory experiences for middle school science students. Teachers discuss the results of various laboratory experiences or enter their own modified versions for others to access. Difficult questions posed by students get picked up and answered in the spirit of friendly communication. Sometimes middle school students themselves get on line to ask a question or report on some class activity. There is no discrimination between ages or roles of conference participants. The richness of personal contact between youngsters, their teachers, college professors and outdoor learning specialists sustains and personalizes the effort.

What makes this computer conference work so well is that the teachers who are a part of it really value the information and exchange it offers them. The conference brings them together to address their own concerns, not to fulfill the agenda of some outsider promoting a new technology.

In our electronic conferences and face-to-face meetings, collegiality abounds. When a new teacher in this project requests help in uploading files to our mainframe storage facility, another teacher helps out. Most important, however, is the fact that the teachers see this as their own project with leadership emerging from the group and expanding the program to meet their own needs.

The Virtual Classroom

Roxanne Hiltz, originator of the term "Virtual Classroom" describes it as a teaching and learning environment. It is located within the EIES system and funded by the

Annenberg Foundation. The Virtual Classroom software supports the types of communication and learning activities available in the "traditional" classroom, including an interaction space like a classroom where the "teacher" or others may "lecture" and where group discussions may take place; a communication structure like "office hours" where student and teacher may communicate privately; the ability to administer and collect and grade tests or assignments; the ability to divide a larger class up into smaller working or peer groups for collaborative assignments; and the equivalent of a "blackboard" where graphical elements such as diagrams or equations may be posted for discussion or note-taking.

The Virtual Classroom allows students to work on course materials whenever they can make the time during a week, instead of at one fixed time. Those with microcomputers at home or work "attend class" from there. There tends to be more "collaborative" or "group" learning in a peer-support and exchange environment; more "active" learning than in the traditional classroom; and easier "self-pacing," or learning at a rate adjusted by the students themselves.

Technology in the hands of sensitive professionals can be molded to respond and adapt to human nature. Competency in communicating the subject matter is enhanced by the instructor's ability to attend to the personal dynamics of the individuals in the learning situation. This can make all the difference. An example arose in an on-line statistics class when many students were falling silent because the were embarrassed and felt shy. Most students did not feel confident enough to enter in a comment that they knew would be read by the whole class. Private messages were sent to the instructor with homework assignments as their content. Students said they wanted to answer the questions but didn't want to enter responses into the conference because they didn't feel that it was worthy of taking the other students time. After several private meetings, the teacher was allowed to copy these messages as conference comments to be read by all. The responses were well done and valuable. Students need a vote of confidence and encouragement. EIES is just the vehicle.

Virtual Management Practices Lab

The conceptual design of "Virtual Management Practices Lab" is premised on the basic idea of the value, if not the necessity, of "experiential learning" in acquiring specialized skills, including management skills. The reason our virtual classroom project worked so well was that the system was modified and reprogrammed when necessary to accommodate the teaching and learning styles of the team. A management lab provides a facility in which to play positional roles and conduct extensive communications in various forms: one to one, many to many, discussions, group meetings, collaborative drafting, deliberations votes leading to decision, etc.

A simulated company was organized through which students practiced business management techniques. It quickly became evident, however, that the Virtual Lab experiment is inherently a joint venture between the system's designers, the course instructor, and the students. Students became so involved in interacting among themselves and operating the simulated business that, by the end of the term, they were able to offer numerous suggestions designed to improve not only the operation of the simulated business but also the conduct of the course itself. Following extensive discussions, several student suggestions were adopted.

Technologies such as EIES and the Virtual Classroom were carefully applied in ways which personalized the teaching environment. They supported learning as a human experience, enhanced organizational socialization and utilized only those aspects of the technology which furthered the goals of the course.

Telecourses with a Personal Touch

NJIT offers telecourses where students enroll for college credit in a course that is transmitted over a local television network. The videotapes also serve as remedial and tutorial aids for students having difficulty coping with a demanding course. Plans are underway to use the videotapes as the core for an Advanced Placement physics telecourse for a local high school consortium. A physics liaison person at each site will be personally involved in the course and will respond to student questions. Periodically a physics instructor from NJIT will participate in a session televised live from the central high school and will interact on the telephone with students from consortium high schools.

Many telecourses are expensively produced. Although the production qualities are often impressive, there is a certain feeling of artificiality. Further, the production costs are far out of the range of most colleges, and the material may not correspond to what is normally covered in the comparable college course.

At the other end of the spectrum are in-house productions with modest budgets which result in a combination of "talking heads" and "writing hands." While this may be a reasonable way to deliver information, this format is somewhat sterile, and tends to turn students off.

NJIT's Physics Department has videotaped a series of weekly lectures through which a viewing student gets the feeling of sitting in an actual lecture hall with other students experiencing a live presentation, not a canned one, with real life demonstrations and interactions with tele-classmates. A pumpkin falls from the sky and smashes on the floor, illustrating Newton's Law of Gravitational Attraction. Students vote as to which way they think a particular friction force is pointing. As in real life, sometimes things don't work out and flubs are made. Students applaud, cheer, and jeer, which makes the experience real and human.

Structuring a telecourse around lectures videotaped in front of a live audience of students, using demonstrations and humorous presentations, adds a sense of realism and a human touch. Opportunity for live interchange with the instructor personalizes a telecourse.

The Candid Classroom

In an effort to make the production of telecourses as natural and transparent as possible, the Instructional Media Center at NJIT has developed a facility known as the "Candid Classroom." It allows faculty to teach via television with little modification of their personal pedagogical techniques. The primacy of human interaction in the classroom is maintained in a natural setting and the video recording process is unobtrusive.

A large variety of teaching and learning styles is accommodated by the flexibility in the design of the candid classroom. Three remotely controlled color television cameras, video switching and special effects, in class monitors for instructor and students, and special lighting fixtures make this possible. The instructor wears a wireless microphone to allow mobility and facilitate access to equipment for demonstrations.

Student questions, comments, and reactions are captured by ceiling mounted student microphones and remote control of the television cameras. With this configuration the entire candid classroom facility can be operated by one staff member with a student assistant. The costs are kept to a minimum through the permanent installation of equipment and the "turn-key" design of the system.

We find that the combination of these conditions tends to relax the faculty quickly so that they can give their best "performance."

Teaching History With Film, Television and Videodiscs

The technology of moving-image media (motion pictures and television) has dramatically altered the nature of some of the most important communication that takes place in modern society. Television news and TV commercials for political candidates are obvious examples. Educators are responsible for training students to be able to identify the ways in which the conventions of television drama force the reinterpretation of history when it is represented on the screen, the ways TV news reporting procedures may bias the news stories we see, and the ways in which advertising copywriters try to influence viewers subliminally to buy their product (or their candidate). In a world of TV news and political advertising -- visual literacy is technological literacy.

A two-hour video compilation has been developed to help teachers introduce their students to the critical analysis of film and television. The study guide which accompanies the compilation includes sample assignments and photocopies of archival documents which allow the teacher to lead the class through a close analysis of the moving image as an historical artifact. Therefore teachers can introduce the students to the critical analysis of camera angles, editing and the other devices used by filmmakers to manipulate their audience at the same time that they train young people in the methods of historical research.

In addition to videotape, the compilation has been produced for distribution in randomly accessible CAV videodisc because the disc offers the most flexibility and is the easiest format for frame-by-frame analysis. The CAV disc can be programmed in such a way that it can be used for interactive lessons, but there are no plans to develop the interactive potentials of the technology, because they are not seen as contributing substantially to the educational objective of the project. The point of the disc is to make it easy for the teacher to access an image or a sequence for class analysis and discussion and facilitate exchange of views and opinions between classmates and teachers, not to replace those people with a computer station keyed to an individualized video monitor.

Interactive Science Teaching With a Simple Videodisc System

NJIT has been developing interactive videodisc (IVD) technology for the larger educational community. In one project this new technology is being developed cooperatively by the Institute and several middle schools. A pilot program involving interactive videodisc technology has been integrated into the already existing network of New Jersey middle school science teachers and teacher-educators previously described. Apple-based IVD systems were loaned to several of the home schools. The project began with a pilot "whiz-kid"-teacher team design in which the computer "whiz-kids" were paired in a complementary one-to-one relationship. This design provides for a pooling of talents: the greater organizational experience and supervisory skills of the adults paired with the sharp creative problem- solving skills, bubbling enthusiasm and fearless explorative behavior of the young.

In the hands of a skilled and sensitive science educator interacting with learners who are turned on by the magical nature of the new tool, the learning process can come alive. Centering science learning around imagery which puts the learners at the controls can provide for an amazing awakening of enthusiastic participation in the learning process. Middle school students are able to learn to author their own interactive videodisc programs using the old reliable Apple IIe, an inexpensive interface and a simple authoring system.

Concluding Observations

One reason why scholars and teachers at NJIT have been so successful in their efforts to integrate the new technologies is that the technical resources and support are readily at hand. Under different circumstances there might be artificial pressures to use the technology more intensively to justify the investment in equipment dedicated to a particular project. At NJIT teachers can approach the technology more informally, not hesitating to limit or adjust the use of a system, feeling free to ask that aspects of it be reprogrammed to suit the demands of their own teaching styles. The existence of the Candid Classroom means that the equipment can be used in a more informal way since its set up does not have to be justified with every use.

There are two divergent reactions to technological innovation in the classroom. On one side of a fence are those committed to promoting the introduction of new technologies. Traditionalists on the other side of the fence resist. They often fear the machines themselves, regarding them as a threat to the fragile human element so crucial for a sound educational process.

At NJIT we are perched squarely on the fence, actively developing technological applications, but always in existing successful and humane educational contexts. The medium is not itself the message. Our nonthreatening applications nurture the human dimensions of learning systems.

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AFTERWORD: THE STS PROPHETS AND THEIR CHALLENGE TO STS EDUCATION

Leonard J. Waks

STS education at secondary and tertiary levels continues to spread throughout North America, Western Europe, and Australia. As this issue of the Bulletin demonstrates, there is activity in a great variety of school subjects and academic disciplines, and a convergence on goals and objectives. However, the Technological Literacy Conferences have called attention to an important tension. Many STS educators are very excited to hear such technology critics as Ivan Illich, Jacques Ellul, and Jeremy Rifkin, judging by the audiences they draw. Others, including informed STS leaders, have gone so far in the opposite direction as to register strenuous objectives to having them on the program, despite the STS commitment to consideration of opposing viewpoints. Bill Stonebarger provides a good illustration. In the latest issue of his Hawkbill Newsletter he says "inviting Rifkin and Illich to be key speakers at a conference on science, technology and society is a bit like inviting the grand dragons of the Klu Klux Klan to keynote a conference on the NAACP. These men plainly hate science and technology. They also hate western democratic societies" (Stonebarger, 1988). Whether or not there is any truth in such statements (I have heard them frequently) they are indications of a deep concern.

I want to address this concern by exploring a tension in the relationship between the cultural critiques of the STS Prophets and the curriculum practices of STS Educators. Our society's acute awareness of the specific problematic of our late industrial society is due in large measure to the writings of a few prophetic individuals, including Jacques Ellul, Ivan Illich, E.F. Schumacher, and Buckminster Fuller. These STS Prophets, who initiated the critique of technology, extended that critique to the system of schools and colleges, which they conceived as a major component of the larger technological system (Waks, 1987a; Waks and Roy, 1987). Yet with STS education the insights of such thinkers have been largely relegated to curriculum content for courses within the system. To put the problem bluntly: the STS curriculum reform effort has not yet accommodated the STS Prophets' critique of the educational system itself, but has at this stage of its development adjusted to the major organizing routines of that system.

To advance a dialogue regarding the long-term goals and transitional strategies of the STS educational reform movement, I will review the critique of late industrial society and its educational arrangements developed by the STS Prophets. My goal is to indicate challenges for further exploration, not to criticize specific STS curriculum frameworks or instructional materials.

The Critique of Industrial Society

Since the end of the eighteenth century the western world developed an economic, social and ideological system, based on scientific-industrial production. Machine power replaced animal and human power, and non-renewable resources replaced renewable resources. Population and resource utilization grew exponentially, and the activities of life came increasingly to be organized in large technological and bureaucratic systems, with decreasing control by individuals over the activities of everyday life. Established ethical

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and religious value systems and social conventions eroded under the challenge of scientific epistemologies and modern secular lifestyles and were displaced by secular concerns--primarily the goal of widespread material affluence through techno-economic growth.

Since the 1960's, in what may be called the late industrial era, this uncritical passion for science, technology, and economic growth has been profoundly challenged. The STS Prophets have called attention to a set of related problems emerging in our era. A partial but significant list would include (a) environmental pollution, soil erosion, the destruction of genetic diversity, (b) depletion of non-renewable natural resources, (c) slow energy growth, limits to nuclear power, nuclear waste management, (d) growing debt, reflected in national government, corporate, and household accounts, (e) the aging population, (f) increasingly over-organized and over-controlled life work and leisure activities, frustrating individual striving to actualize unique potentialities, with these frustrations channelled in aggressive or pornographic fantasy, mental illness, or crimes of violence, (g) an alienated and unincorporated underclass, with associated urban problems of crime, drug abuse, and security, (h) exotic medical technologies (e.g. the artificial heart), the broad availability of which would impose unbearable costs on society, the mere existence of which raises new and unresolvable issues regarding the preservation and termination of life, and (i) emerging technologies such as recombinant DNA engineering and artificial intelligence which make a deep incursion upon our very notions of the meaning of life and its unique value.

The Critique of Education

The STS educators intend to empower citizens to address these problems by infusing STS units through the school curriculum. The STS Prophets, however, have perceived the educational system itself to be central to the problematic of late industrial society. So it would appear appropriate and useful to consider the concerns of the prophets while developing ameliorative educational strategies.

We can sum up the critique of education in the STS Prophets under six headings: (1) reduction knowledge, (2) socialization of technical modes of thinking, (3) technicized learning process, (4) loss of meaning, (5) radical monopoly over learning, and (6) socialization of secular values.

1. Reductive Knowledge and the Disciplines

The reduction of knowledge to normal puzzle solving under disciplinary paradigms is a unique feature of industrial society. Burton Bledstein (1976) describes the process whereby over 200 disciplinary associations came into being between the years 1876 and 1889, the formative years of the scientific-industrial system in the United States. Harvard transformed by the elective system, the new land grant universities with their programs in engineering and agricultural science, the professional schools of management (e.g. the Wharton School at University of Pennsylvania) and new graduate research institutions (e.g. Johns Hopkins) reshaped higher education, the organization of knowledge and the distribution of competence in society. Knowledge has become no longer an expression of an individual's thought and experience in its cultural context, but collective puzzle-solving under a paradigm. This form of knowledge has been extended to the humanities, which in our era have largely exchanged their liberating, humanizing function for elaborate technical puzzles of no general interest. This fragmentation is reflected in the school curriculum, with its disciplinary divisions and pre-digested, discipline-based content.

Interdisciplinary studies, as the term implies, take disciplinary knowledge as a starting point. The challenge to STS education lies in its potential to break away from the vain attempt to piece together fragments of reductive knowledge and restore individual learners the position of central organizers of their knowledge, as (to use Buckminster Fuller's term) "comprehensivists." He states:

> When children stand up, breathing and coordinating exquisitely complex patterns for themselves, get their own balance and start drinking in the patterns of the cosmos and earth, they are spontaneously interested in coordinating the total information--the total stimulation . . . Computers, suddenly making human beings obsolete as specialists, force them back into comprehensivity functioning, which they were born spontaneously to demonstrate (Fuller, 1979, p. 94).

2. Socialization of Technical Modes of Thinking

Mathematics, science and engineering dominate contemporary concerns about the curriculum, with art, music, creative writing, dance and many other so-called "non-cognitive" activities relegated to the periphery. In the late 1950's, after Sputnik, the main concern of national educational policy was to recruit only the best students for science, and provide them with the most enriched curriculum. Today, as we fight the "SONY wars," and are faced with technological competition from South Korea and Taiwan, with their frugal, docile and well-educated workforces, our national policy goal has shifted to science literacy for all students. International studies show U.S. students who take chemistry and physics to trail consistently behind students from most other industrial nations in achievement. There is steady pressure to recruit and train as many students as possible for basic mathematical, scientific, and engineering forms of thinking and problem-solving, despite the evidence that there is very little more room at the top--in positions as scientists and engineers (Carnoy, 1987). When students fail to take an interest in science and technology, this is conceived as a "problem." According to Ellul (1964, p. 349):

> Education ... is becoming oriented toward the specialized end of producing technicians; and as a consequence, toward the creation of individuals ... who conform to the structure and needs of the technical group. The intelligentsia will no longer be a model, a conscience, or an animating intellectual spirit. They will be servants ... of the instruments of technique ... Education will no longer be an unpredictable and exciting adventure in human enlightenment, but an exercise in conformity and an apprenticeship to whatever gadgetry is useful in a technical world. (For an elaboration and critique of Ellul's argument, see Waks, 1987b).

In large measure, STS has been able to get its foot into the curriculum door by its promise to motivate science and technology learning for all students, including those who wouldn't otherwise choose to study science. The "new liberal arts" curricula promoted by the Sloan Foundation for liberal arts colleges make similar promises. Here is a representative set of "new liberal arts" goals from Davidson College (Brockway, 1986, p. 242).

(1) to present engineering principles as part of the liberal arts curriculum;
(2) to recognize that technology and quantitative reasoning should play a central role in that curriculum (their emphasis); and
(3) to recognize that liberal education must include frequent experience with technology and with quantitative methods of problem solving over a wide range of subjects and fields.

Such goals at least suggest that the object of education is the socialization of technical modes of thinking for all learners, regardless of choice of studies, to adjust their intelligence to the demands of the global technological system. This concern may also be related to the ubiquitous "decision-making" units in STS curricula. How is decision-making to be understood? There is a risk that parameters of "rationality" and various preferred rational decision-making techniques, reflecting a scientific-technical mindset, will be imposed (see Aikenhead, 1985). The socialization of the technical mindset is a subtle form of indoctrination, but that is difficult to see when the scientific-technical worldview and value system are still widely and uncritically accepted.

The challenge here is: can STS educators promote and maintain the space for genuinely personal decision-making, based on each learner's heritage (including science, technology, and other cultural traditions) as well as unique personal forms of thinking?

3. Schooling Itself as a Technicized Process

In schooling the process of learning is only rarely an exciting encounter between unique individuals and their global cultural inheritance. Rather, it is itself conceived as a technical process (e.g. Bloom's taxonomy of objectives). Goals and objectives are established in detail, and learners are objectively tested after receiving pre-set treatments. This creates a reassuring illusion of control for bureaucratic officials, but is frequently unsuccessful even in promoting its own narrow goals. As in the workplace, technical approaches strike up against the human barrier; students tune out or drop out or do drugs or commit suicide more frequently than they give in to the regime of programming and re-allocate their energy and time to school treatments.

Narrow behavioral objectives and close control of the curriculum through standardized achievement tests are antithetical to the insights of the STS Prophets and the goals of the STS educators. The challenge for STS educators lies in the creation of alternative forms for the organization, study, and assessment of learning activities which break away from the technical model of research, planning and quantitative assessment while remaining practicable in the organizational context of schools and colleges.

4. The Loss of Meaning

Each person is faced with one *central* question, the question of meaning. This question may be put in many ways. "Why am I alive?" "What am I to make of my precious opportunity to live?" "What purpose can I commit myself to so that, by that commitment I can actualize my unique potentialities?" Socrates asserted that the unexamined life is not worth living. But in most schools (Waldorf schools are an important exception) the question of meaning is conceived as merely "subjective" and relegated to the periphery. Self-exploratory learning activities and personal counseling are available, if at all, only as pressure valves, and eliminated when time or money are short. The expressive potential is eliminated from activities in "serious" subjects such as mathematics and science. Approbation is dependent upon achievement of behavioral objectives or scores on standardized tests reflecting docile compliance with school routines.

The quest for meaning must be rooted in the learner's immediate experience of unique individual value and personal authority, confirmed by the genuine interest which others take in the learner or in his or her expressive products in knowledge, art, or other activities. Meaning is self-making, auto-poesis, and hence antithetical to treatments with pre-determined goals and objectives. Most educational routes are incompatible with genuine respect for learners as persons; rather they are conceived primarily as technical means which push out the coherent quest for personal meaning.

The purposes and values of individuals and their "worlds" are opposite sides of one coin. The world each of us lives in, our own "personal reality," is a reflection of our values and choices. Each of us endows the world with personal meaning. Our values and goals determine the discriminations we make in experience, what we notice, what comes to and holds our attention. Our values determine the questions we raise and pursue, what we come to know, how we organize it, and what it all means. As the children's rhyme expresses it: Pussycat, pussycat where have you been? / I've been to London to visit the Queen / Pussycat, Pussycat what did you see there? / I saw a mouse run under a chair!

The assertion of the unique value of all individuals and their personal realities, and of the need for political institutions in which self-determined individuals can live as they choose and participate in collective self-governance, free from the domination of any authoritative cultural or political force, are certainly among the dominant themes of western democratic civilization. But the limitation of learning to schooling paralyses this power to endow the world with meaning. Illich asserts that a person will "wither away just as much if he is deprived of nature, of his own work, or of his deep need to learn what he wants and not what others have planned that he should learn." He adds:

> The establishment of more schools in Malaysia or Brazil teaches people the accountant's view of the value of time, the bureaucrats view of the value of promotion, the salesman's view of the value of increased consumption, and the union leader's view of the value of work (1973, p. 61).

Here the challenge to STS education is whether its practices can promote and preserve the space for the formation and pursuit of coherent individual purpose and personal meaning in our late industrial technological era?

5. Radical Monopoly Over Learning

Schools, as Illich (1973) states it, create a radical monopoly over learning by redefining it as education. When we accept the educational system's definition of reality then those who learn out of schools are "uneducated." People have natural capacities for learning, healing, consoling, building shelter, and meeting other human needs. The means for satisfaction of these needs are thus abundant so long as people can depend upon what they can do for themselves.

But life in industrial society and life in most classrooms erode these natural capacities. Fuller says succinctly, "the place to study is certainly not in a schoolroom" (Fuller, 1979, p. 100). Lifelong learning in the universal schoolroom creates addictions to scarce products and services generated by the established institutions. Basic satisfactions become scarce "when the social environment is transformed in a manner that basic needs can no longer be met by abundant competence" (Illich, 1973, p. 54). There is a good example in a recent New York Times (March 19, 1988) story about waves of suicide among Native American youths. The tribes have been unable to preserve their rituals of grieving which were effective in draining of some of the anguish of youth suicide and in suppressing further suicides. In the absence of these rituals, Native-Americans have only helpless university-trained psychologists to console them.

On the individual level, schooling frequently dulls learners' natural capacities and shakes their faith that they can shape a self-determined life, without conforming to a pre-determined slot in the technical-professional culture. On a societal level, the establishment of education de-authorizes natural capacities, leaving society with scarce human resources, and escalating and unsatisfiable needs. The challenge here is whether STS educators can share responsibility for learning with individuals and with many other groups in the community, and assist in the restoration of natural capabilities and personal authority.

6. The Socialization of Secular Values

Living frugal, ecologically responsible lives depends upon using personal capabilities in the pursuit of self-chosen meaning. As natural capacities dry up and meaning fades, a space opens for propaganda. The communications media create a "meta-reality" and "meta-needs" for industrially produced goods and services. The Yuppie philosophy is merely an exaggeration of the general result. A poet friend tells me that the meaning of contemporary life is for us to walk all over each other so that we can eat in gourmet restaurants.

Basic education in our society is a contest to get into higher and professional education, and these in turn are routes to scarce niches of power and privilege. To the winners go the spoils--vast inequalities in income and wealth, ecocidal lifestyles. The educational system holds out the promise that every kid can be a winner in this game. In the view of the STS Prophets that is the central problem of education, which serious reform must address.

The promise of universal consumer affluence through education is a promise which cannot be kept. But it divides the world into the haves and the have-nots, the prisoners of addiction and the prisoners of envy. It sustains the urban jungles, with their crime, teen pregnancy, drug abuse, suicide, and general hopelessness. It sustains North/South and Middle East conflicts, with their wars and threats of terrorism (including nuclear blackmail). It generates the demand for energy growth with all the associated problems such as nuclear waste management and risks of meltdown.

Ivan Illich put this challenge succinctly: "People must learn to live in bounds. They cannot be taught" (1973, p. 65). He added:

> It does not matter what the teacher teaches so long as the pupil has to attend hundreds of hours of age-specific assemblies to engage in a routine decreed by the curriculum and is graded by his ability to submit to it (p. 62).
>
> (People) must learn to abstain from unlimited progeny, consumption and use. It is impossible to educate people for voluntary poverty or to manipulate them into self-control. It is impossible to teach joyful renunciation in a world totally structured for higher output ... (People learn these) by living active and responsible lives (p. 65).

This raises the final challenge: can STS education promote and maintain our civilizational values of individual self-determination and social justice in the late industrial society? Can STS education play a significant role in a long-term social process leading to opportunities for active, responsible, self-directed lives for all in ecologically sound and democratically organized societies throughout the world?

Conclusion

In this paper I have pointed to a tension between the critique of education in the STS Prophets and the curriculum practices of STS education. I have indicated six challenges for exploration as STS educators continue with their educational reform efforts. STS educators must strive to place their efforts within the context of a long-range process of global social and technical transformation to assure human survival and well-being. The challenges to the STS Prophets provide useful though sometimes uncomfortable prods to get on with this task. Only the unfolding dialogue can determine whether and how STS education will meet these challenges. The time is now ripe for STS education reform leaders to come to terms with such challenges as they specify long-term goals and transitional strategies.

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BULLETIN OF SCIENCE, TECHNOLOGY & SOCIETY

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The *Bulletin of Science, Technology & Society* is designed to provide a means of communication within as wide a spectrum of the STS community as possible. This includes faculty and students from sciences, engineering, the humanities, and social sciences in the newly emerging groups on university and college campuses, in the high school systems, all of which teach integrative STS subject matters. It also includes professionals in government, industry and universities, ranging from philosophers and historians of science to social scientists concerned with the effects of science and technology, and scientists and engineers involved with the study and policy-making of their own craft; and the concerned general reader. A third category of readers represents "society": all journalists dealing with science and technology impacts in their respective fields; the public interest groups and the attentive public.

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